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Water Quality Monitoring of Saginaw and Grand Traverse Bays

2005 Annual Data Report

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1.0 INTRODUCTION

The Water Bureau (WB) of the Michigan Department of Environmental Quality (MDEQ) is charged with monitoring ambient surface water quality in Michigan. Beginning in June 1998, the MDEQ-WB initiated partial implementation of its Water Chemistry Monitoring Project (WCMP) using a portion of a $500,000 appropriation by the state legislature to the MDEQ-WB for water quality monitoring. The WCMP was a first step towards improving water quality monitoring in Michigan since funding reductions resulted in severely restricted monitoring capabilities. Past limitations in analytical quantification levels further restricted the effectiveness of MDEQ-WB monitoring activities, but recent technological advances in affordable, low-level analytical techniques have been incorporated into the WCMP.

The WCMP is an important component of the statewide surface water quality monitoring activities outlined in the January 1997 report prepared by the MDEQ-Surface Water Quality Division (SWQD) and the Land and Water Management Division (LWMD) entitled, "A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters" (Strategy). The WCMP incorporates the goals of the Strategy, which are as follows:

1. Assess the current status and condition of individual waters of the state and determine whether Michigan's water quality standards are being met;

2. Measure temporal trends and assess spatial comparisons in the quality of Michigan's surface waters;

3. Provide data to support MDEQ water quality programs and evaluate their effectiveness; and

4. Detect new and emerging water quality problems.

The November 1998 passage of the Clean Michigan Initiative (CMI) bond proposal resulted in a substantial increase in annual funding for statewide surface water quality monitoring beginning in 2000. The CMI bond also offers the availability of consistent, reliable funding for surface water quality monitoring over a long period of time, an essential component to realizing the second goal of the Strategy: measuring temporal trends and assessing spatial comparisons in the quality of Michigan's surface waters. Following passage of the CMI bond proposal, the study design of the WCMP was modified and expanded to facilitate use of the CMI funding source in a manner that will help ensure implementation of statewide water chemistry trend monitoring activities capable of more fully realizing the goals set forth in the Strategy. The MDEQ has contracted Great Lakes Environmental Center (GLEC) to assist with the implementation of the WCMP, including the monitoring of Grand Traverse (Lake Michigan) and Saginaw (Lake Huron) Bays.

The WCMP calls for annual water chemistry monitoring on Saginaw and Grand Traverse Bays, as well as selected Michigan streams tributary to the Great Lakes (tributaries), and Great Lakes connecting waters. This report outlines the WCMP activities and the 2005

data results for Saginaw and Grand Traverse Bays. The MDEQ conducted seasonal sampling in Saginaw Bay from 1993 to 1998 and in Grand Traverse Bay beginning in 1998. In 1999, GLEC conducted seasonal sampling for the MDEQ in Saginaw Bay and in Grand Traverse Bay. In 2000 and 2001, the MDEQ conducted seasonal sampling in Saginaw Bay and, in conjunction with the Grand Traverse Band of Ottawa and Chippewa Indians (GTBOCI), Grand Traverse Bay. From 2002 to 2005, GLEC conducted the monthly sampling of Saginaw Bay and seasonal sampling on Grand Traverse Bay. The water quality sampling locations for Saginaw and Grand Traverse Bays are shown in Figures 1 and 2, respectively. The goals of these monitoring efforts have been to:

- Assess water quality trends in the Grand Traverse and Saginaw Bays;
- Evaluate compliance with Michigan Rule 57 Water Quality Values;
- Evaluate the overall effectiveness of the MDEQ's regulatory, pollution prevention and remedial programs; and
- Determine whether the target phosphorus concentrations, established by the "State of Michigan Phosphorus Reduction Strategy for the Michigan Portion of Lake Erie and Saginaw Bay," have been achieved.

This report summarizes monitoring results obtained at Saginaw and Grand Traverse Bays in 2005. Data summaries presented in this report include measures of central tendency, qualitative spatial comparisons and comparisons with Michigan Rule 57 water quality values. In a previously published, more comprehensive report on Saginaw and Grand Traverse Bays (GLEC 2006, available upon request from the MDEQ), monitoring results obtained during 1993 through 2004 were summarized. That report included statistical spatial comparisons and temporal trend analyses, and will be updated with monitoring results from 2005 through 2007 when all results obtained during those years become available.

2.0 SITE DESCRIPTION

2.1 SAGINAW BAY

2.1.1 Physical Characteristics and Monitoring Locations

Saginaw Bay is a large estuary and embayment of Lake Huron on the eastern coast of the state of Michigan that extends southwest 82 km from Lake Huron to the mouth of the Saginaw River in Bay City, Michigan. With respect to morphometry, the bay is essentially divided into inner and outer bay regions, marked by a constriction extending from Point Lookout on the western shoreline to Sand Point on the eastern shoreline (Figure 1). Although the respective surface areas are similar, the inner bay is relatively shallow and only contains approximately 30 percent of the bay's total water volume (Budd *et al.* 1998), with a relative mean depth of 4.6 m. The outer bay has a relative mean depth of 15 m. Seven water quality monitoring stations are located in the inner bay area (Figure 1). The monitoring stations are distributed throughout the inner bay, with stations near the western and eastern shores, the central inner bay region and one station near the Saginaw River outlet.

2.1.2 Hydrologic Influences

Saginaw Bay has a drainage basin seven times larger (ca. 21,000 km^2) than the immediate area of the bay (Budd *et al.* 1998). The Saginaw River, located near the southwestern end of the bay near Bay City, is the dominant source of surface drainage into the bay, accounting for approximately 70 percent of the total drainage of tributaries to the bay and drawing from 80 percent of the bay's total basin area. Consequently, the inner bay is heavily impacted by occasionally large seasonal inputs from the Saginaw River. Saginaw River daily discharge rates vary by season, ranging from 28 million cubic meters per day in the spring to 2.4 million cubic meters per day in the fall (Beeton *et al.* 1967). The outer bay is primarily influenced by Lake Huron.

Circulation patterns within the bay can be quite complex and are driven both by Lake Huron coastal currents and by wind stress (Budd *et al.* 1998). Movement and mixing of water within the bay determines, to a large extent, the concentration and distribution of nutrients, and the seasonal development of biota (e.g. phytoplankton and zooplankton). For example, predominant southwest winds may initiate a counterclockwise circulation pattern in the inner bay and result in water originating from the Saginaw River being pushed against the eastern shore of the bay (Budd *et al.* 1998). Consequently, nutrient concentrations may be greater along the eastern shore with an associated increase in algae concentrations.

2.2 GRAND TRAVERSE BAY

2.2.1 Physical Characteristics and Monitoring Locations

Grand Traverse Bay is located in the northwestern portion of the lower peninsula of Michigan and is connected to Lake Michigan. The total distance from the head to the mouth of the bay is approximately 48 km. The general axis of the bay is north to south

and is divided into western and eastern arms by a peninsula, which extends northward approximately 29 km from the base of the bay in Traverse City. Each arm of the bay is approximately the same width, and both contain a deep basin. West and East Grand Traverse Bay have a maximum depth of 123 and 187 m, respectively. Approximately 75 percent of the volume of the bay lies below a depth of 15 m. Four monitoring stations, positioned at the base and near the northern edge of the central peninsula in each arm, are located in Grand Traverse Bay (Figure 2). The southern sampling station in the western arm is near the mouth of the Boardman River, while the northern station in the eastern arm is located near the mouth of the Elk River.

2.2.2 Hydrologic Influences

The average total daily inflow to Grand Traverse Bay from the watershed is approximately 2.29 million cubic meters per day (Auer *et al.* 1975). There are two primary inflow sources (the Boardman and Elk Rivers) that contribute over 93 percent of the surface water input to the bay: the Elk River at Elk Rapids contributes 1.42 million cubic meters of water per day to East Grand Traverse Bay, and the Boardman River at Traverse City contributes 721,000 cubic meters of water per day to West Grand Traverse Bay. The Elk and Boardman Rivers constitute approximately 60 percent and 30 percent of the tributary flow to the bay, respectively, and are likely the primary source of nutrients and other anthropogenic inputs into the bay. Included in the flow from the Boardman River is potentially 32,000 cubic meters per day (plant capacity) of treated effluent from the Traverse City Wastewater Treatment Plant. The Elk Rapids Wastewater Treatment Plant also contributes up to 1,541 cubic meters per day of treated effluent (permit limit) through the Elk River into East Grand Traverse Bay.

The exchange of water between Grand Traverse Bay and Lake Michigan is significantly influenced by the presence of a sill along the bottom of the bay at its northern extent, which averages approximately 15 meters in depth. The presence of the sill generates a large gyre (ring-like system of currents), which rotates in the northeastern portion of the bay and impedes water exchange with Lake Michigan (Johnson 1975). The primary site of water exchange between the bay and Lake Michigan is at the western edge of the sill, where there is an approximately 43 meter deep trench in the sill. Circulation within the bay is reduced at the southern ends of each arm. This is important with respect to nutrient inputs from the Boardman River, as the flushing rates at the southern base of West Grand Traverse Bay can be dramatically lower than other bay regions.

2.2.3 Historical Water Quality Data

The water quality of Grand Traverse Bay was previously reviewed by Shuey *et al.* (1992). This review noted that Grand Traverse Bay was an oligotrophic system with high overall water quality (from Auer *et al.* 1975). Total phosphorus concentrations at open bay stations averaged 0.0079 mg/L, one of the lowest concentrations in the Great Lakes. Macrophyte beds present in the southern portion of the west arm of Grand Traverse Bay were attributed to the discharge of nutrients from the wastewater treatment plant in Traverse City, via the Boardman River. Additional treatment at this plant in recent years has eliminated up to 90 percent of the phosphorus from effluent discharged into the Boardman River. Shuey *et al.* (1992) also noted that although phosphorus was

the primary pollutant/limiting nutrient of concern in Grand Traverse Bay, the levels had not increased in the open bay since 1975 and were actually lower than in 1975. Phosphorus concentrations in the southern portion of the western arm were slightly higher, probably a result of nutrient loading from the Boardman River and storm sewers. Further studies in 1998 (Grand Traverse Bay Watershed Initiative 2000) indicated a steady decline in total phosphorus concentrations in the west arm, which is consistent with the total phosphorus concentrations throughout the entire bay. The decline in phosphorus can be partially attributed to improvements in the wastewater treatment plant on the Boardman River from 1973 to 1992. The continued decline since 1992 may be partially attributed to the increase in zebra mussel density in the bay. If zebra mussels are playing a significant role in the nutrient balance in Grand Traverse Bay, the mussels could cycle phosphorus into the sediments through metabolic routes, or hold the phosphorus in an unavailable form. It is reasonable to conclude that infestations of zebra mussels in Grand Traverse Bay influence the cycling and availability of nutrients.

Levels of nitrate were not considered problematic and averaged 1.03 mg/L in the open Bay (Shuey *et al.* 1992). Concentrations in the southern portion of the west arm of the bay were 1.06 mg/L, indicating that there was no build-up of nitrate associated with the Boardman River. More recent measurements of nitrate/nitrite nitrogen (Grand Traverse Bay Watershed Initiative 2000) were very similar overall to the nitrogen concentrations measured by Auer *et al.* (1976) and Shuey *et al.* (1992).

Chlorophyll *a* concentrations in the open bay and sub-embayments (e.g., Suttons Bay, Northport Bay and Bowers Harbor) averaged 0.618 and 0.800 µg/L, respectively, in 1992, with a bay-wide average of 1.04 µg/L in 1998 (Grand Traverse Bay Watershed Initiative 2000). Historically, average concentrations in the southern portion of the west arm were slightly higher than open bay stations, indicating a higher biomass of phytoplankton near the mouth of the Boardman River.

3.0 METHODS

3.1 SAMPLING OF SAGINAW AND GRAND TRAVERSE BAYS

3.1.1 Sampling Dates

Sampling was scheduled monthly on Saginaw Bay and seasonally (spring, summer and fall) on Grand Traverse Bay. However, sampling was not always completed as scheduled due to equipment failure. Table 1 provides a summary of the sampling dates and the parameters (i.e. conventional, limnological, *in situ* and metals – see section 3.1.2) that were sampled during each event at each station. Below are anomalies to the defined schedule.

- Samples were not collected from Saginaw Bay in April or August at all stations or at stations 060062, 090252, 060063 and 090250 in October, 2005.
- *In situ* measurements of pH, conductivity, dissolved oxygen (DO) and water temperature were not completed at stations 320188, 790134, 090252, 090250 and 060063 in November, 2005.
- No samples were collected from Grand Traverse Bay during the fall.

3.1.2 Sample Collection, Handling and Analysis

Sampling stations are identified in Figures 1 and 2. Surface water samples were collected and handled in accordance with MDEQ-approved procedures at depths of one meter, except at Saginaw Bay station 060062, which was also sampled at mid-depth. Formerly station #068062M, the mid-depth sample was designated as station 060078 in 2000.

Limnological and conventional parameters (see Table 2) were either analyzed in the field using standardized techniques or by the MDEQ Environmental Science and Services Division (ESSD) Laboratory using Environmental Protection Agency (EPA)-approved methods. DO, conductance, pH and water temperature measurements were collected *in situ* using a multiparameter measurement instrument. Mercury (Hg) and trace metals (Table 2) samples were collected and handled using ultra-clean techniques in accordance with EPA Method 1669. Hg was analyzed by the Wisconsin State Laboratory of Hygiene (WSLH) using EPA Method 1631, and the trace metals cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) were analyzed by the WSLH using EPA Method 1638. Hg and trace metals quantification and detection levels for the WSLH are presented in Table 3.

3.1.3 Data Analysis

An analysis of water quality data collected during 2005 in Saginaw and Grand Traverse Bays was completed. Water quality data were summarized for each parameter in box and whisker plots, and the results of basic statistical analyses were summarized in tables. Station 060062 in Saginaw Bay was sampled at two depths; all of the data from the two depths (stations 060062 and 060078) were averaged for analysis. Examination of the analytical laboratory data indicated that several measurements were

flagged with laboratory result remark codes. Of these codes, the following were predominant:

CCB = Continuing calibration blank exceeded quality control criteria.

LCQC = Laboratory control exceeded quality control criteria.

MSD = Matrix spike duplicate exceeded quality control criteria.

ND = Observed result was below the quantification level.

T = Reported value is less than the reporting limit. Result is estimated.

W = Reported value is less than the method detection limit.

Data below analytical quantification or detection levels (i.e., uncensored data), including negative values, were used directly in the analyses. Support for the use of uncensored data is provided by Porter et al. (1988) and Gilliom et al. (1984).

3.1.4 Comparison with Michigan Rule 57 Water Quality Values

Data obtained for Hg and trace metals were compared with applicable Rule 57 water quality values. These values were developed in accordance with the Michigan Part 4 Rules (MAC 1999). For Hg, the applicable Rule 57 water quality value is the wildlife value (WV); and for Cd, Cr, Cu, Pb, Ni and Zn, the applicable Rule 57 water quality value is either the final chronic value (FCV) or the human non-cancer value (HNV), depending upon the station and the metal. The FCV for Cd, Cr, Cu, Pb, Ni and Zn is hardness-dependent and was calculated for each station using station-specific hardness data. Ambient Cd, Cr, Cu, Pb, Ni and Zn concentrations are for total metal, whereas the FCVs for these metals are expressed as dissolved metal. Therefore, a direct comparison between ambient total metal concentrations and their Rule 57 water quality values cannot be made. This is not an important consideration when the ambient total metal concentration is less than the applicable Rule 57 water quality value. However, in the event that the total metal concentration exceeds the Rule 57 water quality value, the available data cannot show whether the ambient concentration of dissolved metal exceeds the Rule 57 water quality value. Additional, more sophisticated monitoring or the application of a suitable translator value would be necessary to resolve an ambiguity of this nature, and caution must be exercised when drawing conclusions from the available data.

3.2 OVERVIEW OF WATER QUALITY PARAMETERS

In order to evaluate water quality in Saginaw and Grand Traverse Bays, the range of water quality parameters was reduced to two subsets of relevant indicators of water quality. The first subset of parameters are accepted “limnological” indicators and the second subset is composed of other “conventional” water quality indicators (Table 2). In addition, trace metals (Cd, Cr, Cu, Pb, Ni and Zn) and Hg were analyzed (Table 2).

3.2.1 Overview of Limnological Parameters

- **Ammonium Nitrogen.** Ammonium nitrogen is the primary form of ammonia in surface water. Ammonium nitrogen is generated by heterotrophic bacteria as a primary end product of decomposition of organic matter, either from proteins or from other nitrogenous organic compounds. Ammonium nitrogen is easily assimilated by aquatic plants. Among blue-green algae, the highest growth rates occur with ammonium nitrogen as the nitrogen source. The distribution of ammonium nitrogen in fresh water is highly variable within lakes, both seasonally and spatially, and is dependent on the level of productivity of the lake and the extent of organic pollution. Because of its rapid assimilation by algae, ammonium nitrogen concentrations are usually low in trophogenic zones of well-oxygenated waters.

- **Chlorophyll *a*.** Because all green plants contain chlorophyll *a*, the concentration of chlorophyll *a* is an indirect method to estimate the amount and activity of phytoplankton in the water. Many limnologists argue that lower concentrations of chlorophyll *a* are associated with better water quality, although certain amounts are a normal part of a functioning aquatic ecosystem. Phytoplankton growth rates are dependent on nutrient supply (phosphorus, nitrogen, etc.), sunlight and temperature. Given these requirements and lake-dependent characteristics, chlorophyll *a* concentrations tend to fluctuate seasonally, with peak levels in spring or summer. However, phytoplankton (and therefore, chlorophyll *a*) are also subject to predation by zooplankton, which may cause dramatic decreases in the chlorophyll *a* concentration.

- **Temperature and Dissolved Oxygen.** Temperature and DO play an important part in the ecology and chemistry of aquatic ecosystems. The parameters are related because the solubility of DO in water is primarily a function of temperature. The solubility (or saturation) of DO is defined as the concentration in water that is in equilibrium with the atmosphere at one atmosphere of pressure. Temperature and DO profiles are commonly measured in lakes to determine if stratification occurs during summer months and during winter if the lake is covered with ice. Thermal stratification results in a thermocline, which inhibits the vertical mixing of surface and bottom waters. During stratification, bottom oxygen concentrations can be depleted as a result of bacterial decomposition of organic material, and the resultant anoxic conditions can lead to a release of dissolved inorganic phosphorus from the sediments. Thermal stratification usually occurs in large, deep lakes and is typically removed in the fall and spring when surface water temperatures near 4ºC (maximum density) and strong winds induce a seasonal "turn-over". Shallow lakes often continue to be internally mixed by prevailing winds and therefore do not often stratify.

  Surface water samples usually do not exhibit oxygen depletion because of the establishment of equilibrium conditions with the atmosphere and therefore are usually at or near oxygen saturation. Similarly, surface water temperatures are usually a function of ambient air temperatures and mixing of the upper water column.

- **Nitrate+Nitrite Nitrogen.** Nitrate and nitrite nitrogen are inorganic forms of nitrogen that affect the productivity of fresh waters and are utilized by aquatic plants and

bacteria for growth. The nitrogen requirements of microorganisms are approximately ten times that of phosphorus. Because nitrogen/phosphorus ratios exceed 10:1 in most freshwater systems, nitrogen is not usually a limiting nutrient. Nitrates and nitrites exist in the natural environment and arise from the bacterial oxidation of ammonia and organic nitrogen compounds. In well-oxygenated waters, the dominant component of the nitrate+nitrite (NO_x) measurement is nitrate.

The primary artificial sources of nitrate and nitrite nitrogen to surface waters are atmospheric input (wet and dry deposition) and fertilizers, which enter receiving waters in the form of runoff from agricultural, urban and recreational lands. Other sources can include any land use that increases the loading of organic debris to runoff water, such as animal waste. This organic debris can ultimately be broken down into oxidized nitrogen compounds.

- **pH.** The number of free hydrogen ions in water represents its pH. pH values can vary between zero and 14; pH values near zero are characterized as acidic, and values near 14 are considered basic. In Michigan, the pH of water typically ranges between 6.5 and 8.5, primarily due to the presence of calcium carbonate.

- **Secchi Disk Transparency Depth.** Secchi disk transparency depth is a measure of the transparency of water to light. Water clarity is critical because it influences the depth of light penetration (photic zone) and can modify the range and distribution of aquatic macrophytes as well as phytoplankton and a variety of algal species. Secchi disk transparency is influenced by the absorption characteristics of both the water and its dissolved and particulate matter. Northern Michigan lakes have relatively hard water with excess calcium carbonate and, as a result, there may be a chemical clouding or “whiting” which occurs during the summer peak photosynthetic periods. In addition, as lakes become more eutrophic, the higher algal productivity may reduce water clarity and further limit the effective photic zone.

- **Total Kjeldahl Nitrogen.** Total Kjeldahl nitrogen (TKN) is a measure of dissolved and particulate organic nitrogen plus any ammonia present. The dissolved fraction of organic nitrogen often constitutes up to 50 percent of the total soluble nitrogen. Except for ammonia, the nitrogen in this group of compounds is tightly bound in organic molecules and is slowly released for plant use only by bacterial degradation. The presence of high levels of Kjeldahl nitrogen is indicative of soil erosion, surface water runoff and organic wastes. Much of the organic nitrogen is absorbed by lake sediments.

- **Total Orthophosphate**. Orthophosphate, an oxidized form of phosphorus, is primarily a measure of biologically available phosphorus and is often the most limiting nutrient in freshwater aquatic ecosystems. Although phosphorus concentrations in surface waters are usually reported in terms of total phosphorus, only orthophosphate can be immediately utilized by aquatic plants. Orthophosphate is rapidly removed from the water column by algae, and therefore levels are usually very low. Typically, measured concentrations are near instrument detection limits. Because orthophosphate is readily utilized by plants, inputs to the Bays from tributaries and storm sewers can have a significant localized effect on macrophyte

growth.

- **Total Phosphorus.** Total phosphorus includes soluble orthophosphate and the insoluble phosphates complexed in organic and inorganic compounds. Although only orthophosphate is bio-available, total phosphorus is commonly used as a relative index of phosphorus load. Generally, total phosphorus concentrations greater than 10 µg/L may contribute to increased aquatic plant growth and are indicative of impaired water quality. Inputs from tributaries and storm sewers may cause localized aquatic macrophyte growth, particularly in areas where currents do not readily flush accumulations of influent water and associated suspended solids.

3.2.2 Overview of Conventional Parameters

- **Hardness and Total Alkalinity.** Water hardness is often used as an assessment of water quality, and is determined by the content of calcium and magnesium salts (primarily combined with bicarbonate and carbonate or with sulfates), chlorides and other anions of mineral acids. In calcareous lakes and waters typical of Michigan, most of the hardness in water is a result of calcium carbonate. Similarly, alkalinity refers to the quantity and types of compounds present in the water that shift the pH to the alkaline side of neutrality. The property of alkalinity is usually imparted by the presence of carbonates, bicarbonates and hydroxides.

- **Calcium, Magnesium and Sulfates.** Both calcium and magnesium are nutrients required by higher aquatic plants for normal metabolism. Calcium can exhibit noticeable seasonal and spatial variation, and levels of calcium can decrease as a result of the precipitation of calcium carbonate during summer months (May through September). In contrast to calcium concentrations, magnesium compounds are more soluble than calcium and therefore are rarely precipitated. Consequently, magnesium concentrations normally fluctuate very little within a water body.

  Sulfur (measured as sulfate), in both organic and inorganic forms, is also required by all living organisms and is reduced to sulfhydryl groups (-SH) during protein synthesis. Sulfur has both natural (rocks and soil/sediment) and anthropogenic (atmospheric deposition as a result of the combustion of fossil fuels) sources. Within water, nearly all assimilation of sulfur is as sulfate, and the usual range for freshwater systems is 5 to 30 mg/L, with an approximate mean of 11 mg/L (Horne and Goldman 1994).

- **Total Chloride**. The chloride ion is not usually a significant parameter in freshwater, open lake systems; however, anthropogenic sources (road salting, industrial sources and municipal wastewaters) of chloride can greatly modify natural concentrations of this anion. The average chloride concentration in natural freshwater is 8.3 mg/L (Livingstone 1963).

- **Conductivity.** The specific conductance (conductivity) of lake water is a measure of the resistance of a solution to electrical flow. As the ion content of the water increases, so does the conductivity (resistance to electrical flow will decrease). The conductivity of a typical bicarbonate lake is closely related to the concentration of the

major ion species (calcium, magnesium, sodium, potassium, carbonate, sulfate and chloride). Conductivity varies seasonally and yearly, depending on the relative distribution of these major ions within the water column.

- **Potassium and Sodium.** Potassium and sodium are chemicals required by aquatic plants for growth. Natural levels of these minerals are normally relatively low in aquatic environments. Elevated levels are likely an indication of anthropogenic pollution from road salts, human wastes, animal wastes and fertilizers.

- **Dissolved and Suspended Solids.** The measurement of dissolved solids is used as an estimate of the inorganic materials (i.e., magnesium carbonate, chlorides, etc.) dissolved in water. Similarly, suspended solids (total non-filtered residue) are particulates or compounds that are suspended and generally insoluble in water. There can be considerable temporal and seasonal variation in these values, depending on temperature, dissolved oxygen and pH.

- **Total Organic Carbon.** Total Organic Carbon (TOC) is a measure of both the dissolved and particulate organic carbon in the water that is bound as part of living matter (i.e., algae and diatoms) and by decomposition. A high organic content is associated with increased growth of microorganisms, which contribute to the depletion of oxygen. Therefore, elevated TOC concentrations may be associated with depleted oxygen concentrations. TOC also determines, to some extent, the bioavailability of contaminants to organisms, thereby affecting both acute and chronic toxicity.

- **Turbidity.** Turbidity is a direct measure of water clarity, and is primarily influenced by total suspended solids. The major sources of turbidity include phytoplankton, small particulate matter from shoreline erosion, re-suspended bottom sediments and organic detritus from wastewater and/or stream discharges.

The importance of each of the above limnological and conventional parameters and the trace metals and Hg concentration data are discussed below within the context of the reported 2005 water quality data for Saginaw and Grand Traverse Bays.

4.0 RESULTS AND DISCUSSION

Limnological and conventional water quality data are summarized for Saginaw Bay in Tables 4 through 10; trace metals and Hg data for Saginaw Bay are provided in Table 11. Limnological and conventional water quality data for Grand Traverse Bay are summarized in Tables 12 through 15. Due to the missed autumn sampling event, no trace metals or Hg data were collected in 2005 from Grand Traverse Bay.

4.1 SAGINAW BAY

4.1.1 Limnological Parameter Data

4.1.1.1 Ammonium Nitrogen (Ammonia)

Ammonia concentrations varied between 0.002 and 0.75 mg/L in 2005. Except for station 090252, mean ammonia concentrations were approximately 0.01 mg/L (Figure 3). At station 090252, located near the mouth of the Saginaw River, the mean ammonia concentration was 0.025 mg/L. However, if the exceptionally elevated concentration observed in June (Table 8) is removed, the mean ammonia concentration at this station was also approximately 0.01 mg/L. Generally, ammonia concentrations were most elevated in June.

4.1.1.2 Chlorophyll *a*

Chlorophyll *a* concentrations exceeding 4 µg/L are considered indicative of mesotrophic conditions (moderately enriched), and those exceeding 10 µg/L are indicative of eutrophic conditions (greatly enriched). During 2005, chlorophyll *a* concentrations ranged between 1.1 and 22 ug/L. Mean chlorophyll *a* concentrations exceeded 4 ug/L at all stations, and station 090250 had a mean chlorophyll *a* concentration exceeding 10 ug/L (Figure 4). Overall, the lowest chlorophyll *a* concentrations were observed at station 060063 (Table 10).

4.1.1.3 Temperature and Dissolved Oxygen

Water temperature ranged between 8.5 and 24.6 °C in 2005 while DO concentrations ranged between 6.9 and 12.6 mg/L during the same time period. Mean temperature (Figure 5) and DO measurements (Figure 6) demonstrated a relatively consistent relationship at all stations; surface DO levels ranged from 75 percent to greater than 100 percent of saturation at all stations. The lowest percent saturation was observed at station 090252 in June (Table 8). The oxygen saturation levels observed in 2005 are sufficient to provide adequate oxygen for aquatic organisms.

4.1.1.4 Nitrate + Nitrite Nitrogen

During 2005, concentrations of nitrate ranged between 0.002 and 1.0 mg/L, and concentrations of nitrite ranged between 0.001 and 0.027 mg/L. NO_x concentrations were greatest and most variable at station 090252 (Figures 7 and 8). The lowest mean concentration of nitrate was observed at station 320189. Nearly all mean nitrite

concentrations were less than 0.005 mg/L; the lowest mean concentration of nitrite was observed at station 060063. Because nitrogen levels from all sources (including TKN, see below) in Saginaw Bay exceed phosphorus levels by greater than a ratio of 10:1, phosphorus is the primary limiting nutrient for aquatic plant growth. However, if phosphorus concentrations are not limited, continued elevated inputs of nitrogen into Saginaw Bay may lead to increases in primary productivity.

4.1.1.5 pH

In 2005, pH values ranged from 7.2 to 8.6. Mean pH values were generally between 8.0 and 8.5 (Figure 9). However, mean pH values of 7.7 and 7.9 were observed at stations 060062 and 320189, respectively. The reported pH values are within normal limits of expected values in Michigan.

4.1.1.6 Secchi Disk Transparency Depth

Based on the trophic state classification offered by Chapra (1997), secchi disk transparency depth data collected in Saginaw Bay during 2005 was typical of lakes characterized as mesotrophic (< 13 feet secchi disk transparency depth) to eutrophic (< 6.5 feet secchi disk transparency depth). The greatest mean secchi disk transparency depth was at station 060062; the smallest was at station 320189 (Figure 10). Monthly measurements ranged between 2.0 and 16.0 feet.

4.1.1.7 Total Kjeldahl (Organic) Nitrogen

Concentrations of TKN during 2005 ranged from 0.22 to 0.68 mg/L, and were most elevated at station 090252 (Figure 11). The majority of stations had mean TKN concentrations between 0.3 and 0.4 mg/L; station 060062 had the lowest observed mean TKN concentration. Overall, TKN concentrations were most elevated in September.

4.1.1.8 Orthophosphate

Orthophosphate is readily used by algae and other aquatic vegetation, and concentrations are expected to be relatively low, as long as nitrogen is not limiting. In Saginaw Bay, orthophosphate concentrations ranged between 0.001 and 0.007 mg/L in 2005. The lowest mean concentrations were observed at stations 320189 and 060063; the greatest mean concentration was observed at station 090250 (Figure 12). Station 090252, located near the mouth of the Saginaw River, showed the most variability in orthophosphate concentrations during 2005.

4.1.1.9 Total Phosphorus

Concentrations of total phosphorus during 2005 varied between 0.007 and 0.043 mg/L. Mean concentrations of total phosphorus were always greater than 0.01 mg/L (Figure 13), indicating that Saginaw Bay is a mesotrophic waterbody. Station 090252 near the mouth of the Saginaw River had the greatest mean total phosphorus concentration; concentrations never fell below 0.015 mg/L during the sampling period (Table 8). The

lowest mean total phosphorus concentration was observed at station 790134. Stations 090252 and 090250 had mean total phosphorus concentrations exceeding the target total phosphorus concentration of 0.015 mg/L (International Joint Commission 1987); all other stations had at least one (and often more) measured concentrations exceeding this threshold.

4.1.2 Conventional Parameter Data

4.1.2.1 Hardness and Alkalinity

Hardness ranged between 100 and 185 mg/L during 2005. With the exception of station 090252, mean hardness ranged between 115 and 130 mg/L; station 090252 had a mean hardness value of 153 mg/L (Figure 14). The reported values are typical of hard water lakes in Michigan.

Alkalinity values in 2005 ranged between 71 and 129 mg/L, and were most elevated at station 090252. Mean alkalinity values generally ranged between 80 and 95 mg/L with the exception of station 090252, which had an average value of 107 mg/L. Station 090252 also had the most variability in alkalinity values measured throughout 2005 (Figure 15).

4.1.2.2 Calcium, Magnesium and Sulfate

During 2005, concentrations of calcium ranged between 23.3 and 48.9 mg/L. Mean calcium concentrations were always between 30 and 40 mg/L with the exception of station 320189, which had a mean calcium concentration of 29.5 mg/L (Figure 16). The most elevated mean calcium concentration was observed at station 090252 (Table 8); this station also exhibited the most variability in calcium concentrations throughout 2005.

As expected, magnesium concentrations varied less than calcium concentrations; magnesium concentrations ranged between 7.9 and 15.3 mg/L in 2005 (Figure 17). Nearly every mean magnesium concentration was between 8.5 and 11.0 mg/L. However, station 090252 had a mean magnesium concentration of 13.0 mg/L.

Sulfate concentrations ranged between 14 and 26 mg/L in 2005. Mean concentrations were always between 15 and 20 mg/L with the exception of station 090252, which had a mean concentration of 22 mg/L (Figure 18). Station 090252 also showed the most variability in sulfate concentrations throughout 2005.

4.1.2.3 Total Chloride

Concentrations of chloride ranged between 8 and 45 mg/L in 2005 (Figure 19), and mean chloride concentrations were generally two to four times higher than the natural freshwater average of 8.3 mg/L reported by Livingstone (1963). Station 090252, located near the mouth of the Saginaw River, had the greatest mean chloride concentration (36 mg/L), while the remaining stations had concentrations between 15 and 21 mg/L.

4.1.2.4 Specific Conductance

Conductivity values measured in 2005 ranged from 231 to 482 umho/cm. The most elevated values were observed at station 090252 near the mouth of the Saginaw River; conductivity values at other stations were very similar (Figure 20). The greatest variability in conductance throughout 2005 was observed at stations 790134 and 090252.

4.1.2.5 Potassium and Sodium

Potassium concentrations ranged from 1.1 to 2.6 mg/L during 2005; mean concentrations of potassium ranged between 1.4 and 2.1 mg/L (Figure 21). Sodium concentrations ranged between 5.1 and 22.4 mg/L and mean concentrations ranged between 8.4 and 19.0 mg/L (Figure 22). Station 090252 had a mean sodium concentration of 19.0 mg/L; all other stations had concentrations less than or equal to 11.1 mg/L. Stations 790134 and 090252 exhibited the greatest variability in potassium and sodium concentrations throughout 2005 (Figures 21 and 22).

4.1.2.6 Dissolved and Suspended Solids

Dissolved solids concentrations ranged between 130 and 310 mg/L during 2005. Mean concentrations were generally between 180 and 205 mg/L; however, the mean dissolved solids concentration at station 090252 was 260 mg/L (Figure 23).

Concentrations of suspended solids ranged between 0 and 16 mg/L, and there were many instances where measurable concentrations could not be detected. Mean suspended solids concentrations were generally between 2 and 6 mg/L (Figure 24). Suspended solids concentrations were most elevated in October and November.

4.1.2.7 Total Organic Carbon

During 2005, TOC concentrations ranged between 1.4 and 6.6 mg/L. Mean concentrations of TOC were generally between 3 and 4 mg/L (Figure 25), with the exceptions of station 060063 (4.2 mg/L) and station 090252 (5.7 mg/L). The greatest variability in TOC concentrations throughout 2005 was observed at station 790134; the least variability was at station 320188.

4.1.2.8 Turbidity

Turbidity values in Saginaw Bay during 2005 ranged from 1.1 to 11.0 NTU. Mean turbidity values ranged between 2.0 and 4.0 NTU except at stations 320188 and 790134, which averaged 5.7 and 4.6 NTU, respectively (Figure 26). Stations 320188, 790134 and 090252 showed a relatively large variation in turbidity values throughout 2005.

4.1.3 Trace Metals and Mercury Data

Hg and trace metals concentrations were quantified for samples collected at four stations in 2005; one sample was collected per station during each sampling event.

4.1.3.1 Cadmium, Chromium and Lead

Concentrations of Cd were relatively low and ranged between approximately 0.002 and 0.009 ug/L in 2005; mean concentrations were always less than 0.007 ug/L (Figure 27). Station 320189 had the lowest mean Cd concentration in 2005.

Cr concentrations were also relatively low in 2005; many reported concentrations were less than zero. Mean concentrations ranged between 0.02 and 0.1 ug/L (Figure 28). The most elevated mean Cr concentration was observed at station 090252 (0.26 ug/L).

Pb concentrations ranged between approximately 0.03 and 0.4 ug/L in 2005. Mean concentrations ranged between approximately 0.09 and 0.16 ug/L (Figure 29). The lowest mean concentration was observed at station 060063.

All mean concentrations of Cd, Cr and Pb met the applicable Michigan Rule 57 water quality values at all stations during 2005 (Table 11). Additionally, no single measurement exceeded the applicable Michigan Rule 57 water quality value.

4.1.3.2 Copper, Nickel and Zinc

Cu concentrations in Saginaw Bay during 2005 ranged between approximately 0.5 and 2.6 ug/L, and were most elevated in June. Mean concentrations ranged between 0.6 and 1.5 ug/L (Figure 30); the most elevated mean Cu concentration was at station 090252 (1.47 ug/L).

Concentrations of Ni were relatively low and ranged between 0.8 and 1.5 ug/L in 2005. Mean Ni concentrations were less than 1.0 ug/L except at station 090252, which had a mean Ni concentration of 1.3 ug/L (Figure 31).

Zn concentrations were also relatively low; concentrations ranged between approximately 0.9 and 5.7 ug/L. One exceptionally elevated Zn concentration was observed at station 320189 during September (5.69 ug/L). Mean Zn concentrations were between 1.6 and 2.6 ug/L in 2005 (Figure 32).

All mean concentrations of Cu, Ni and Zn measured at the four selected sites met the applicable Rule 57 water quality values in 2005 (Table 11). Additionally, no single measurement exceeded the applicable Michigan Rule 57 water quality value.

4.1.3.3 Mercury

The toxicity of Hg is well established for biological systems, and the potential for Hg to bioaccumulate is a major concern in aquatic communities. In Michigan, the Rule 57 water quality value for Hg is 1.3 ng/L. This value was never exceeded in 2005. Mean

Hg concentrations ranged from approximately 0.4 to 0.5 ng/L (Figure 33). The most elevated mean Hg concentrations were observed at stations 060062 and 090252 (0.68 ng/L).

4.1.4 Conclusions - Saginaw Bay

Nutrient data collected from Saginaw Bay in 2005 are indicative of mesotrophic to eutrophic conditions. Levels of total phosphorus are relatively constant, and continue to be at or above the target total phosphorus concentration of 0.015 mg/L. Concentrations of NO_x are also relatively high, but the data indicate that phosphorus is the limiting nutrient in the Bay. Productivity is quite high in Saginaw Bay, likely due to the elevated phosphorus concentrations. This observation is supported by the relatively high concentration of chlorophyll *a* at all of the stations, and by water clarity measurements based on the secchi disk transparency depth.

Levels of most of the conventional parameters were consistent with concentrations noted in regional lakes. Concentrations of calcium, magnesium, sulfate and chloride were generally consistent among sampling stations, with elevated concentrations occasionally noted at station 090252, near the mouth of the Saginaw River. Hardness, alkalinity, pH, specific conductance and dissolved and suspended solids concentrations were generally typical of regional lakes at most sampling stations. Higher dissolved solids concentrations were noted near the mouth of the Saginaw River and may reflect the contribution of the river into Saginaw Bay.

Concentrations of limnological and conventional parameters at various sampling stations in Saginaw Bay appear to be influenced by the physical characteristics of the Bay, especially circulation patterns established by prevailing winds (causing the re-suspension of sediment), inflow from Lake Huron and the Saginaw River, predominant lake currents and water depth. Nutrient loading from the Saginaw River, and the watershed in general, may flow along the southeastern region of the Bay and impact the sampling stations in this area. Although this circulation pattern (counterclockwise) does not always occur, it may occur often enough to enhance nutrient loading in this region of Saginaw Bay. This observation is somewhat supported by the data which indicate that, over time, the open water stations and stations in the northwestern region exhibit slightly lower concentrations of numerous nutrients. These data indicate that reductions in source nutrients within the Saginaw River and the Saginaw Bay watershed are needed.

Trace metals and Hg concentrations always met applicable Michigan Rule 57 water quality values in 2005.

4.2 GRAND TRAVERSE BAY

4.2.1 *Limnological Parameter Data*

4.2.1.1 Ammonium Nitrogen (Ammonia)

Concentrations of ammonia during 2005 ranged between 0.008 and 0.018 mg/L. The lowest mean concentration was observed at station 280289 (0.009 mg/L); stations 450132 and 280288 had the most elevated mean concentrations (0.013 mg/L) (Figure 34). The greatest variability in ammonia concentrations was observed at station 450132, located near the mouth of the Boardman River.

4.2.1.2 Chlorophyll *a*

Chlorophyll *a* concentrations ranged between 0.9 and 2.1 ug/L at all stations in 2005. Mean concentrations varied little (Figure 35); the lowest mean concentration was at station 280288 (1.0 ug/L) and the most elevated mean concentration was at station 450132 (1.7 ug/L). Chlorophyll *a* concentrations measured in Grand Traverse Bay were characteristic of oligotrophic lakes.

4.2.1.3 Temperature and Dissolved Oxygen

Water temperature (Figure 36) and DO concentrations (Figure 37) measured during 2005 varied a great deal because of the seasonality inherent in the sampling. However, temperature and DO were very similar between sampling locations. Water temperature ranged between approximately 1 and 23 °C and DO concentrations ranged between approximately 8.7 and 14.5 mg/L. Regardless of the temperature and DO variability, DO levels at all four sampling stations indicated well-oxygenated surface waters conducive to supporting aquatic life.

4.2.1.4 Nitrate + Nitrite Nitrogen

Concentrations of NO_x in Grand Traverse Bay were relatively low in 2005. Individual and mean nitrate concentrations varied little (Figure 38); the minimum concentration measured was approximately 0.19 mg/L and the maximum concentration measured was 0.27. Mean nitrate concentrations ranged between 0.22 and 0.26 mg/L. Nitrite concentrations also varied very little in 2005. Values ranged between 0.001 and 0.007 mg/L and mean concentrations ranged between 0.003 and 0.004 mg/L (Figure 39). Nitrite concentrations were always more elevated during the summer.

4.2.1.5 pH

Values of pH measured during 2005 varied little (Figure 40); the minimum pH observed was approximately 7.7 and the maximum was 7.9. pH values measured in Grand Traverse Bay were consistent with those measured in regional lakes.

4.2.1.6 Secchi Disck Transparency Depth

The secchi disk transparency depth measured in Grand Traverse Bay during 2005 varied between 34 and 43 feet. The secchi disk transparency depth varied little between stations; however, water clarity was generally greater in the eastern arm (Figure 41). The water clarity measured in 2005 at all stations is indicative of excellent water quality and oligotrophic conditions.

4.2.1.7 Total Kjeldahl (Organic) Nitrogen

Concentrations of TKN ranged between 0.14 and 0.29 mg/L during 2005. Mean concentrations of TKN were reasonably consistent between stations and were at levels characteristic of oligotrophic lakes (Figure 42). Station 450132 showed the greatest variability in TKN concentrations measured in 2005.

4.2.1.8 Orthophosphate

Available mean phosphorus (orthophosphate) levels were very low in 2005; all reported values were either less than the reporting limit or non-detectable (Figure 43).

4.2.1.9 Total Phosphorus

Total phosphorus concentrations ranged between 0.002 and 0.007 mg/L. The greatest mean concentration was observed at station 450132 near the mouth of the Boardman River (0.006 mg/L); the smallest mean concentration was at station 450133 (0.003 mg/L) (Figure 44). Total phosphorus concentrations measured in 2005 are indicative of oligotrophic conditions.

4.2.2 Conventional Parameter Data

4.2.2.1 Hardness and Alkalinity

Values of hardness and alkalinity were relatively consistent at all stations in 2005, and were typical of lakes in Michigan. Hardness values ranged between 123 and 141 mg/L (Figure 45) and alkalinity values ranged between 97 and 102 mg/L (Figure 46). The smallest mean values for hardness and alkalinity were observed at station 450133 (124 and 99 mg/L, respectively). The most elevated mean hardness value was at station 280289 (133 mg/L); the most elevated mean alkalinity value was at station 280288 (101 mg/L).

4.2.2.2 Calcium, Magnesium and Sulfate

Concentrations of calcium, magnesium and sulfate were very consistent between stations in 2005. Mean calcium concentrations ranged between approximately 31 and 35 mg/L (Figure 47), mean magnesium concentrations were near 11 mg/L for all stations (Figure 48) and mean concentrations of sulfate ranged between 17 and 18 mg/L (Figure 49). Station 280289 had the most variability in calcium and magnesium concentrations in 2005; sulfate concentrations were most variable at station 280288.

4.2.2.3 Total Chloride

Total chloride concentrations measured in 2005 varied little; mean concentrations were identical between sites (Figure 50). All stations had the same total chloride concentration during a given sampling date.

4.2.2.4 Specific Conductance

Conductance values were relatively stable and very similar between sampling locations; values ranged between 275 and 295 umho/cm. Mean values ranged between 284 and 286 unho/cm (Figure 51).

4.2.2.5 Potassium and Sodium

Potassium and sodium concentration measured in 2005 varied little; potassium concentrations were between 1.2 and 1.3 mg/L and sodium concentrations were between 5.9 and 7.9 mg/L. Mean values were similar between stations for both parameters (Figures 52 and 53).

4.2.2.6 Dissolved and Suspended Solids

Dissolved solids concentrations during 2005 were 190 mg/L at all stations during both sampling events (Figure 54). Suspended solids concentrations in Grand Traverse Bay were below the quantification limit for all samples, indicating that Grand Traverse Bay is an oligotrophic water body.

4.2.2.7 Total Organic Carbon

TOC concentrations varied little during 2005; concentrations varied between 1.2 and 3.0 mg/L. The greatest mean concentration was observed at station 450132 near the mouth of the Boardman River (2.3 mg/L); the smallest mean concentration was observed at station 280288 in the east arm of Grand Traverse Bay (1.5 mg/L) (Figure 55). Mean TOC concentrations in the east arm were less than those measured in the west arm.

4.2.2.8 Turbidity

Turbidity values measured in Grand Traverse Bay in 2005 were below quantification levels in all samples. These data indicate that Grand Traverse Bay is an oligotrophic water body.

4.2.3 Conclusions - Grand Traverse Bay

Based on total phosphorus, chlorophyll *a* and water clarity, Grand Traverse Bay can be classified as an oligotrophic water body with excellent water quality. Overall, the concentrations of measured parameters were very similar between sampling stations. In some instances, concentrations are somewhat more elevated at station 450132 near the mouth of the Boardman River. This indicates the possible influence of Traverse City, the major population center in the Grand Traverse Bay watershed which discharges effluent

to the Boardman River, on the water quality of Grand Traverse Bay.

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FIGURES

FIGURE 1. SAGINAW BAY MONITORING STATIONS.

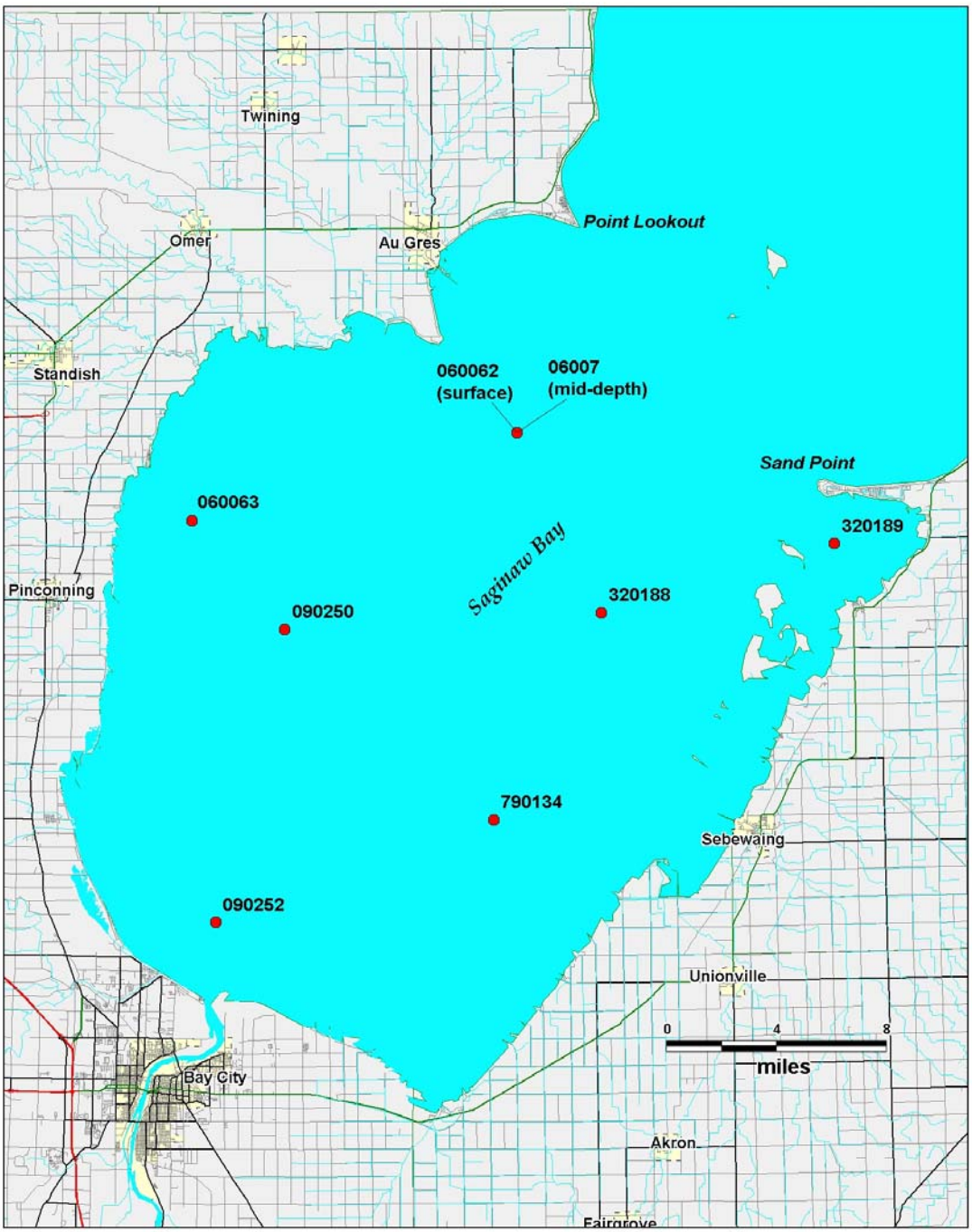


FIGURE 2. GRAND TRAVERSE BAY MONITORING STATIONS.

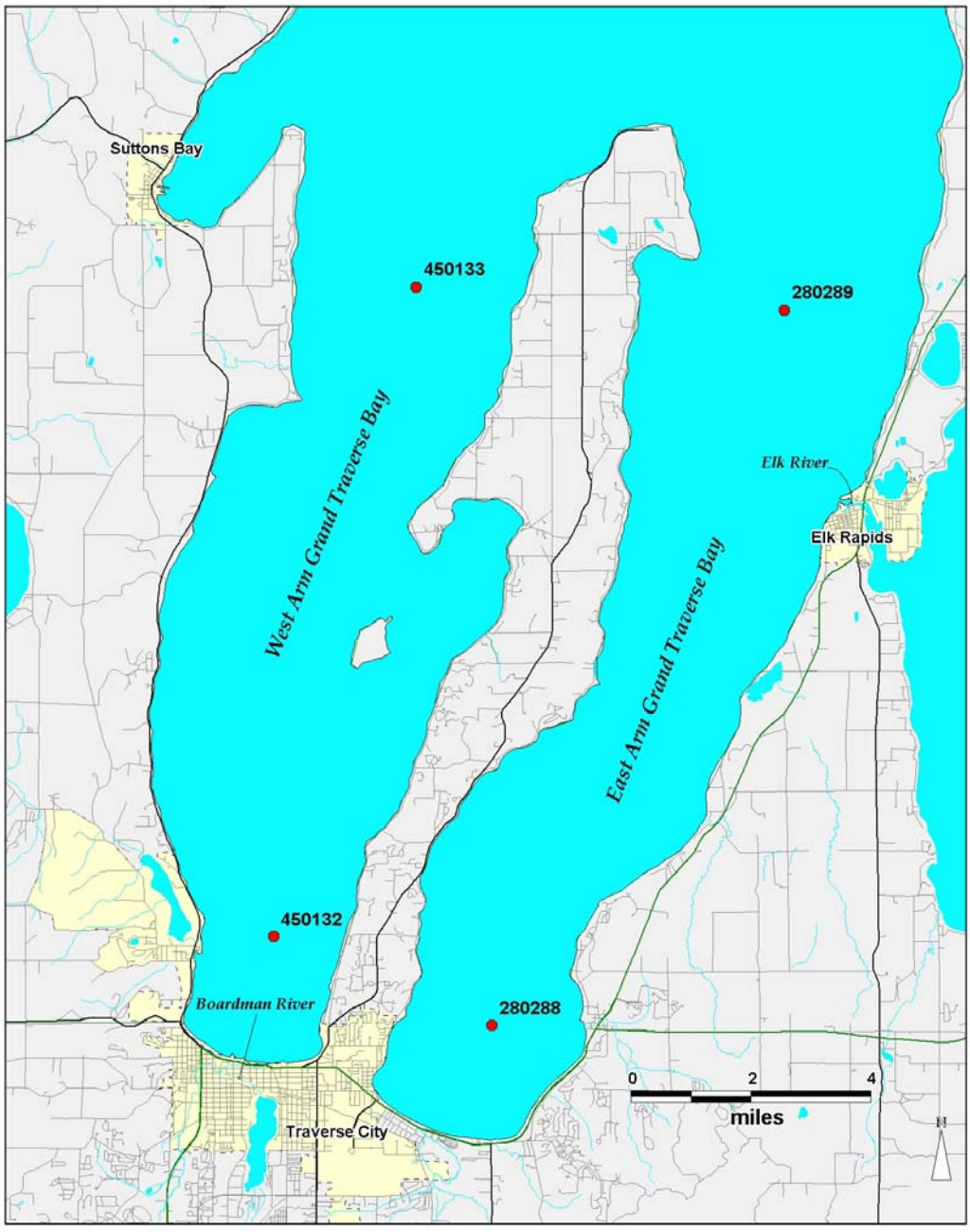


FIGURE 3. BOX PLOT OF AMMONIA CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

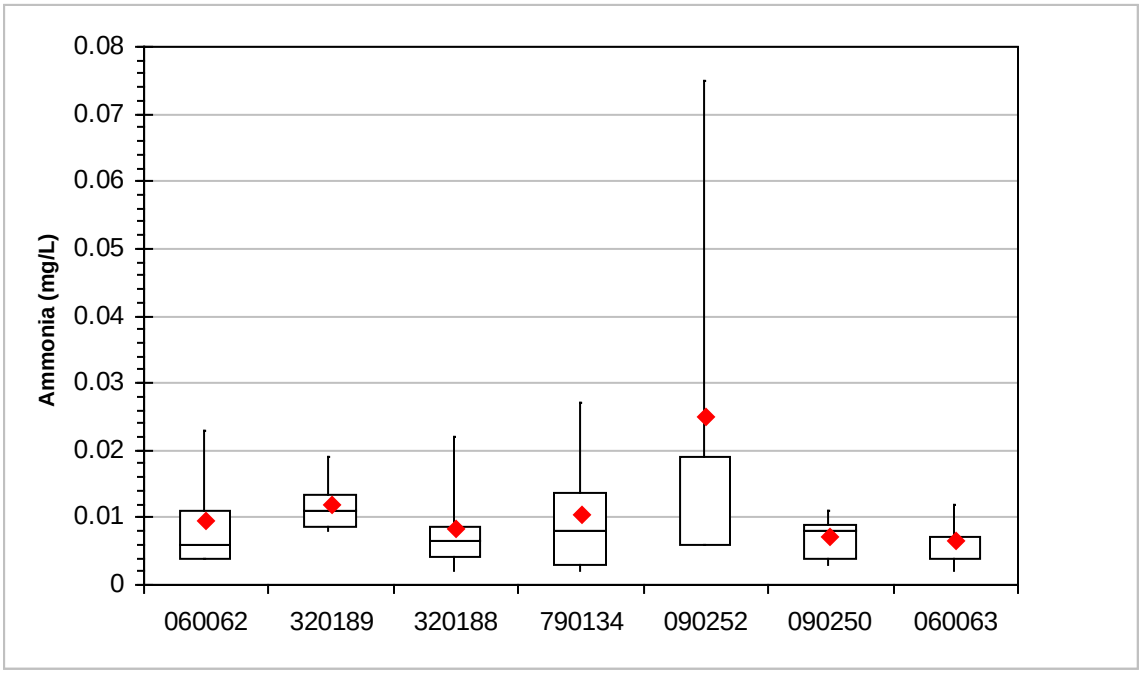


FIGURE 4. BOX PLOT OF CHLOROPHYLL *A* CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

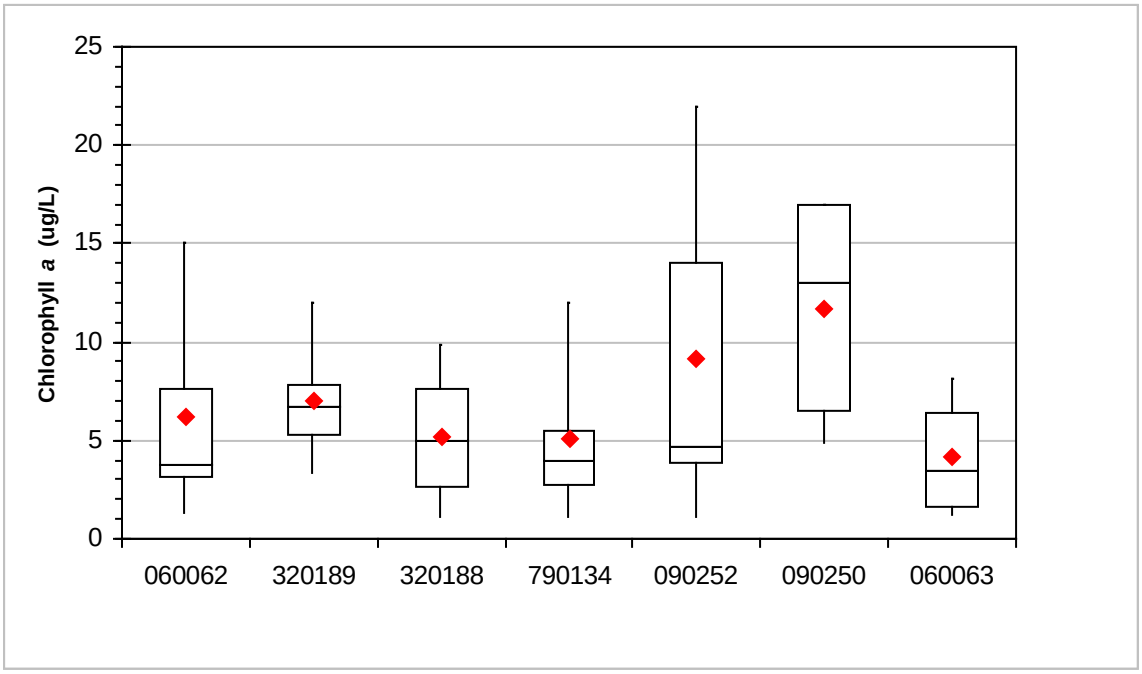


FIGURE 5. BOX PLOT OF TEMPERATURE IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

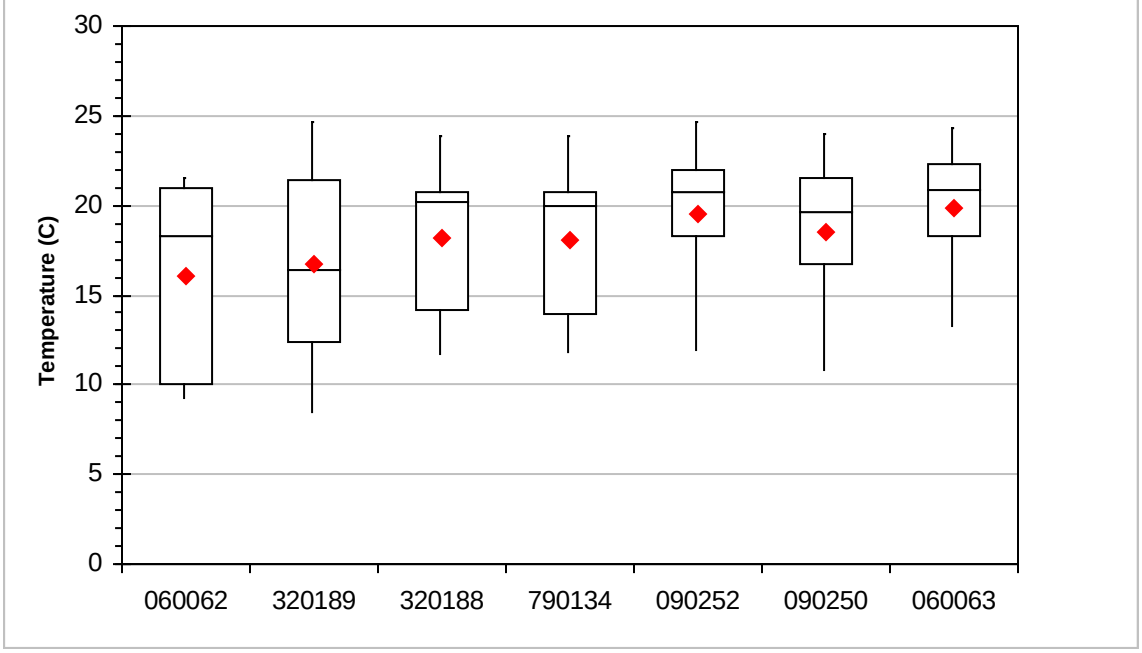


FIGURE 6. BOX PLOT OF DISSOLVED OXYGEN CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

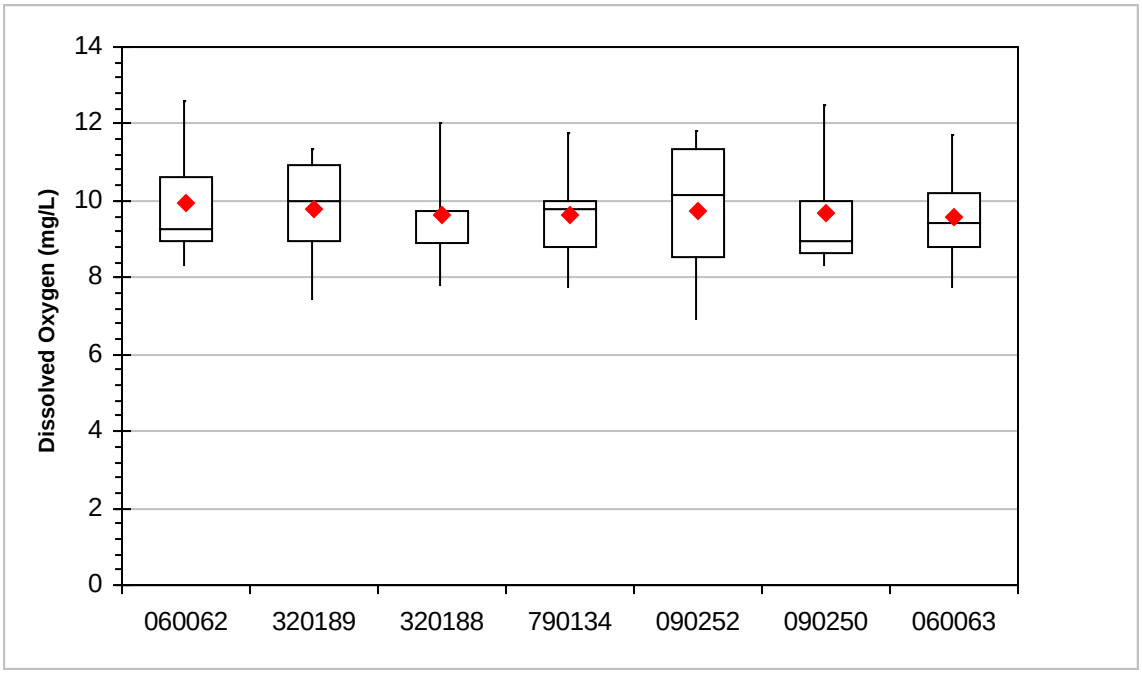


FIGURE 7. BOX PLOT OF NITRATE CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

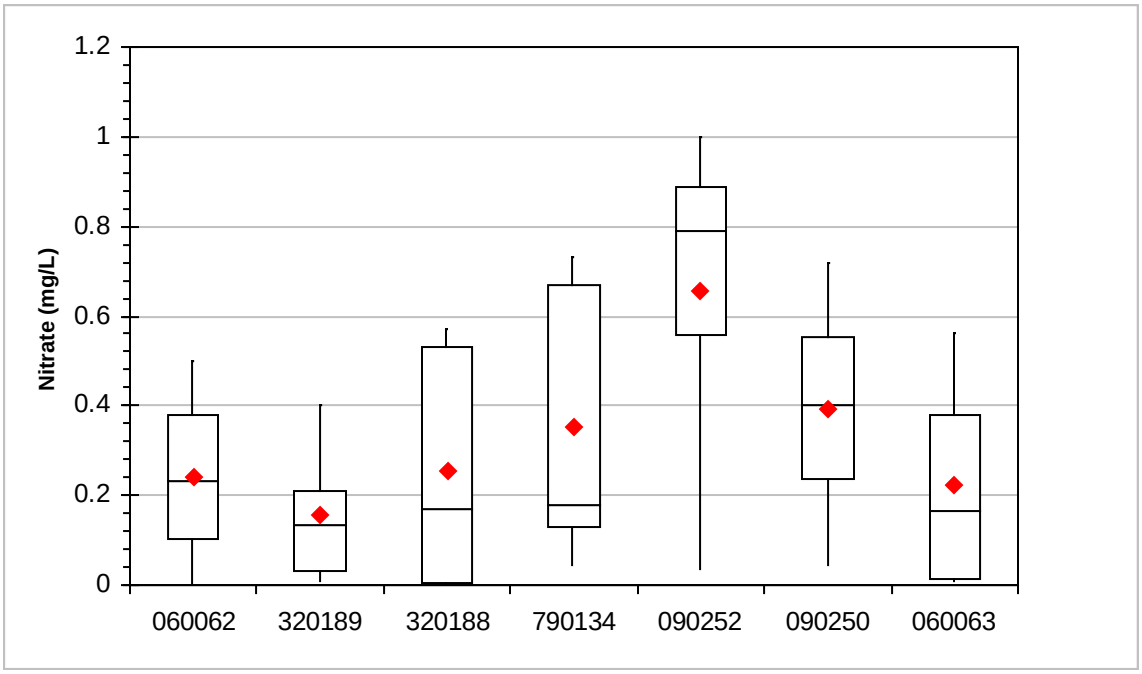


FIGURE 8. BOX PLOT OF NITRITE CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

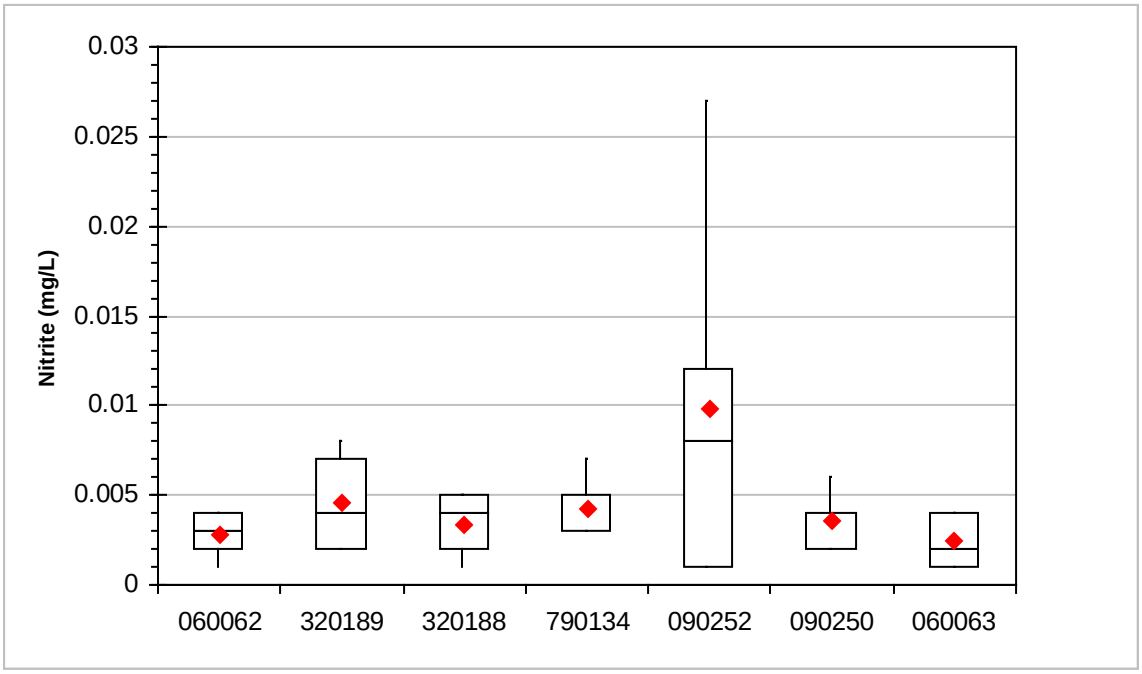


FIGURE 9. BOX PLOT OF PH IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

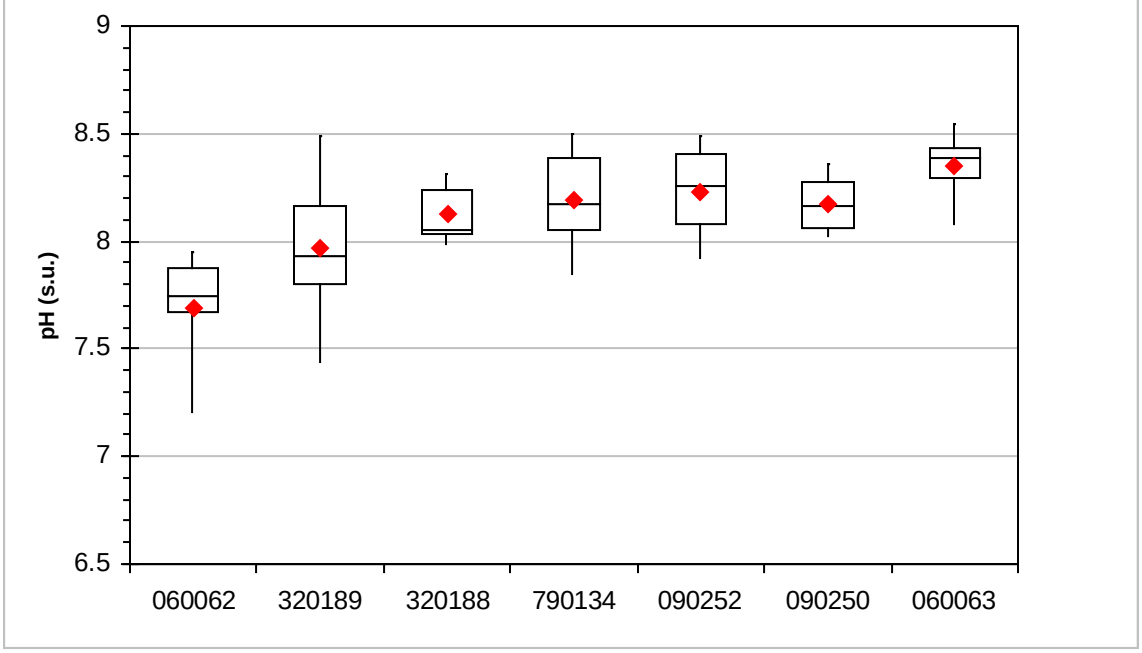


FIGURE 10. BOX PLOT OF SECCHI DISK TRANSPARENCY DEPTH IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

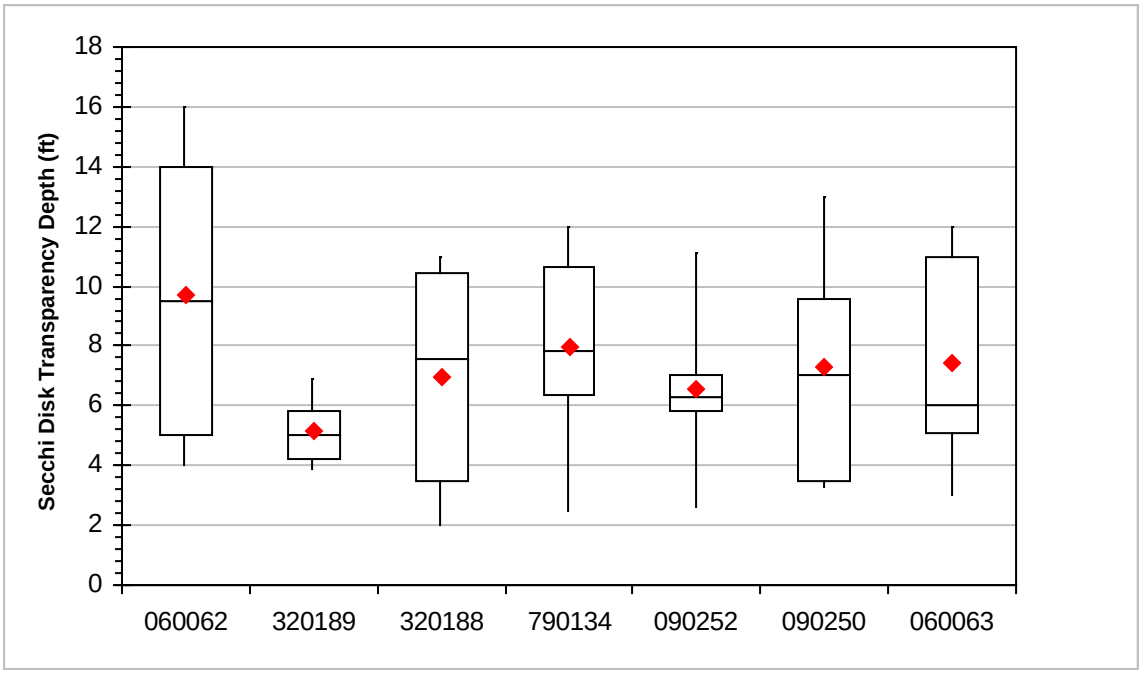


FIGURE 11. BOX PLOT OF TOTAL KJELDAHL NITROGEN CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

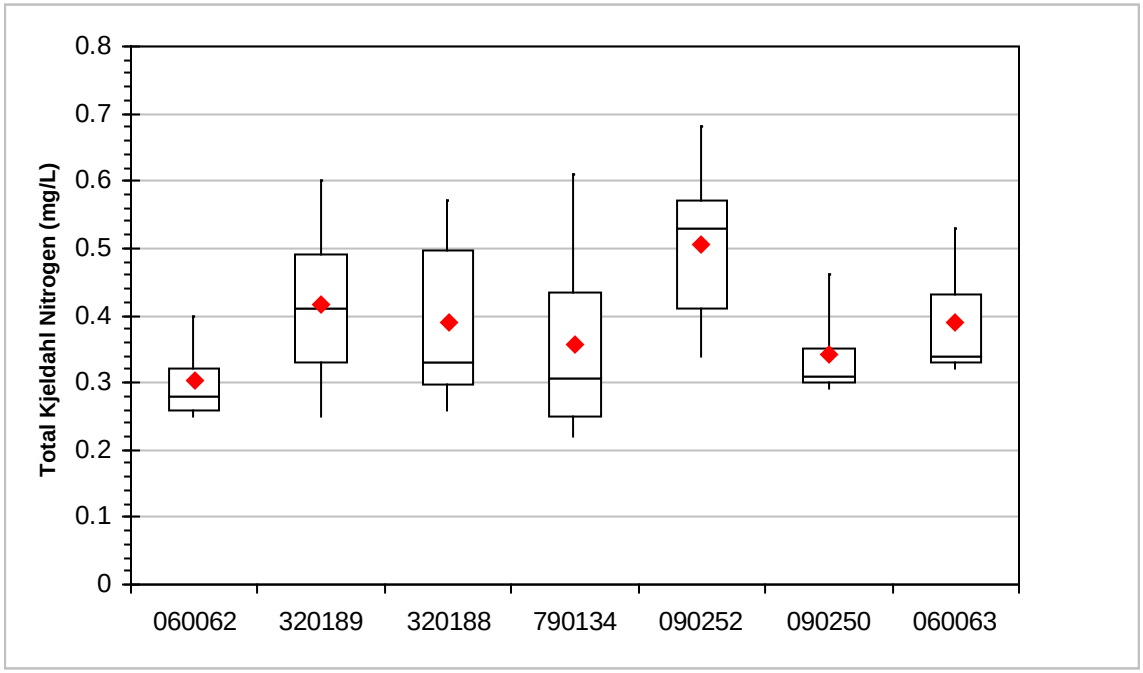


FIGURE 12. BOX PLOT OF ORTHOPHOSPHATE CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

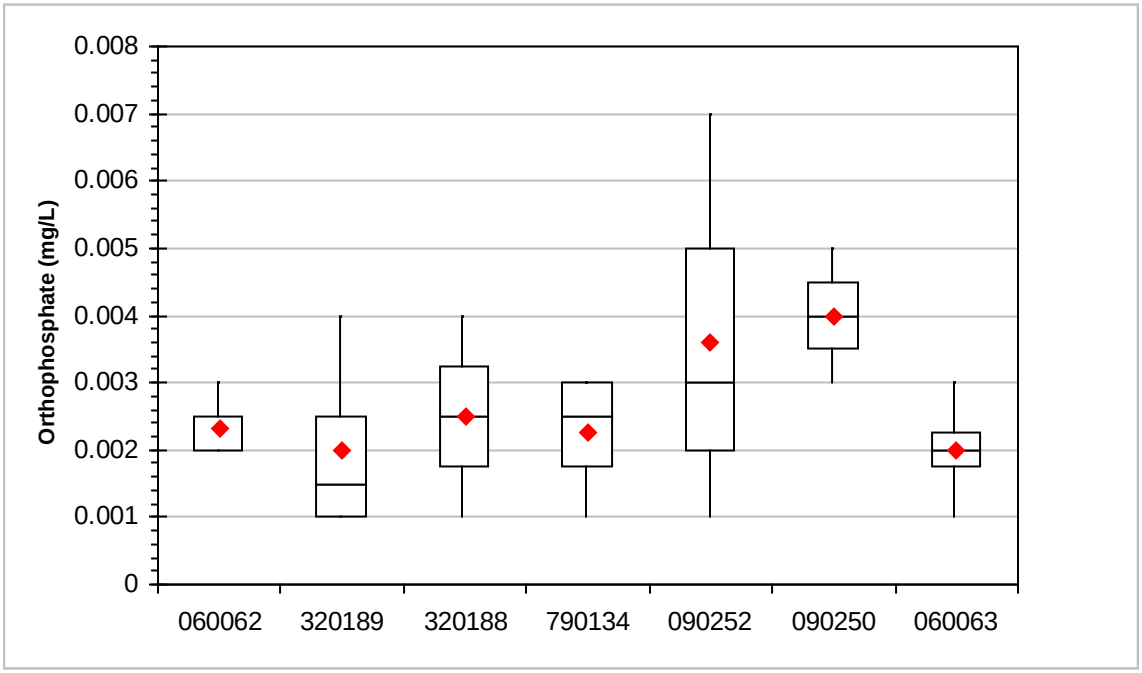


FIGURE 13. BOX PLOT OF TOTAL PHOSPHORUS CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

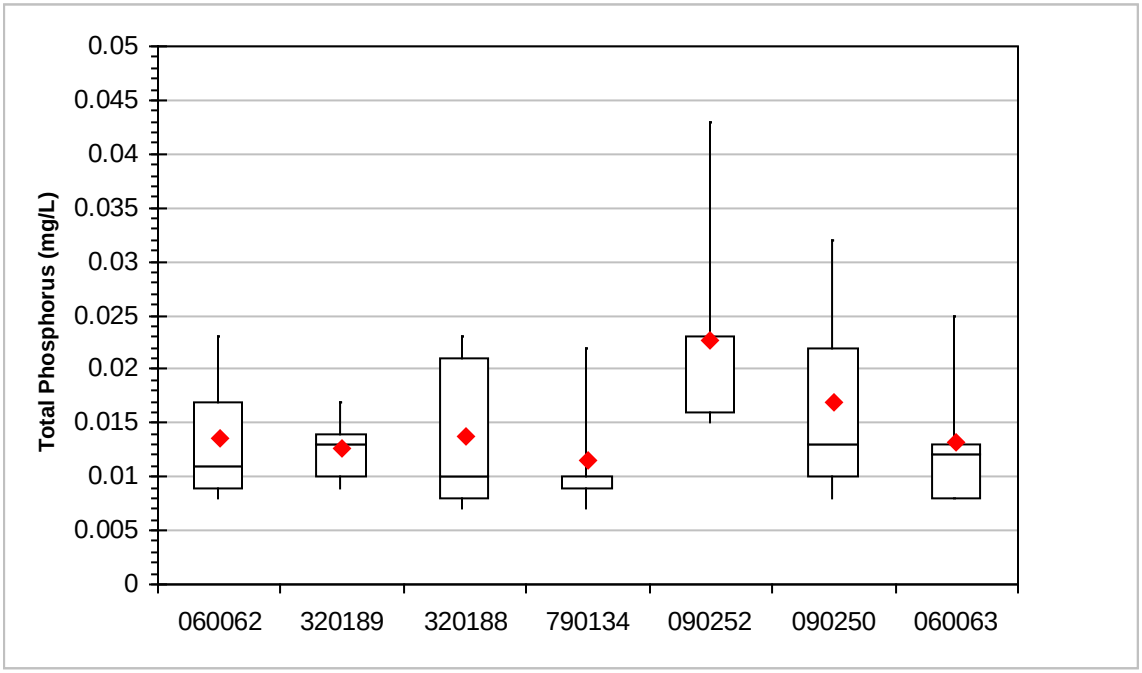


FIGURE 14. BOX PLOT OF HARDNESS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

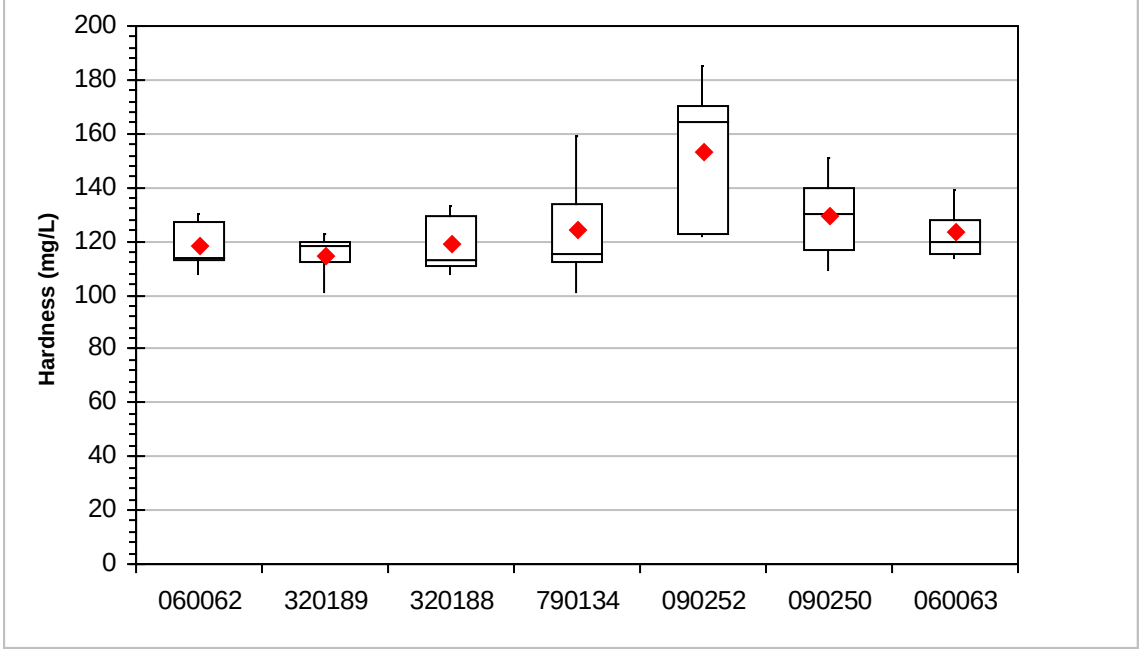


FIGURE 15. BOX PLOT OF ALKALINITY IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

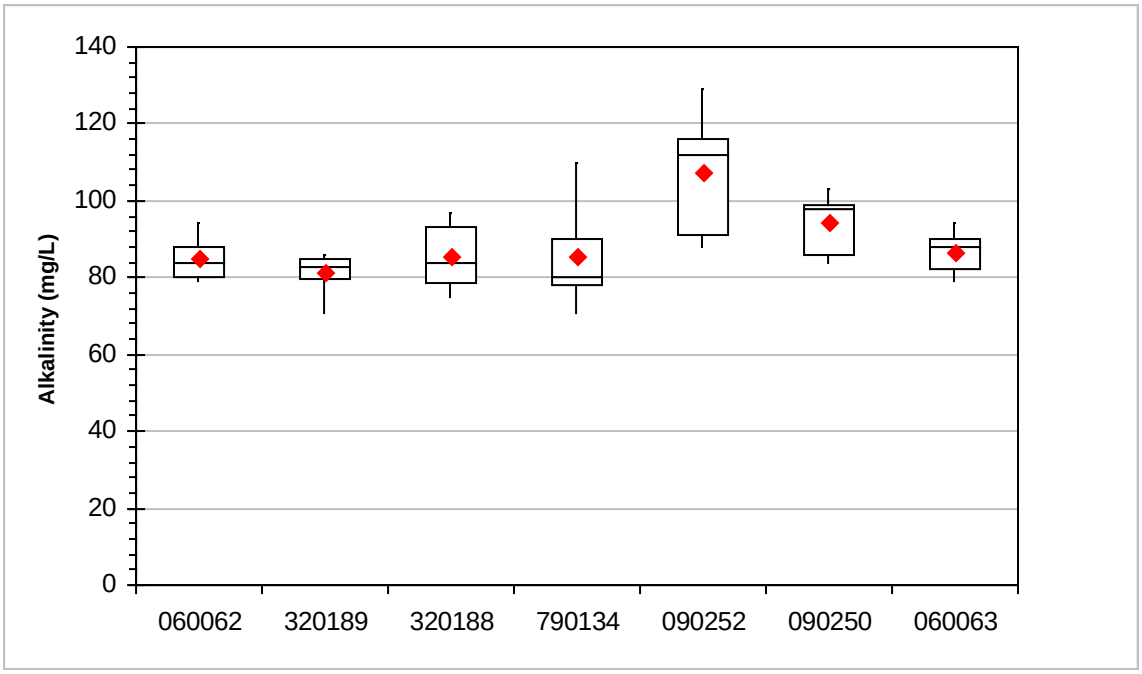


FIGURE 16. BOX PLOT OF CALCIUM CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

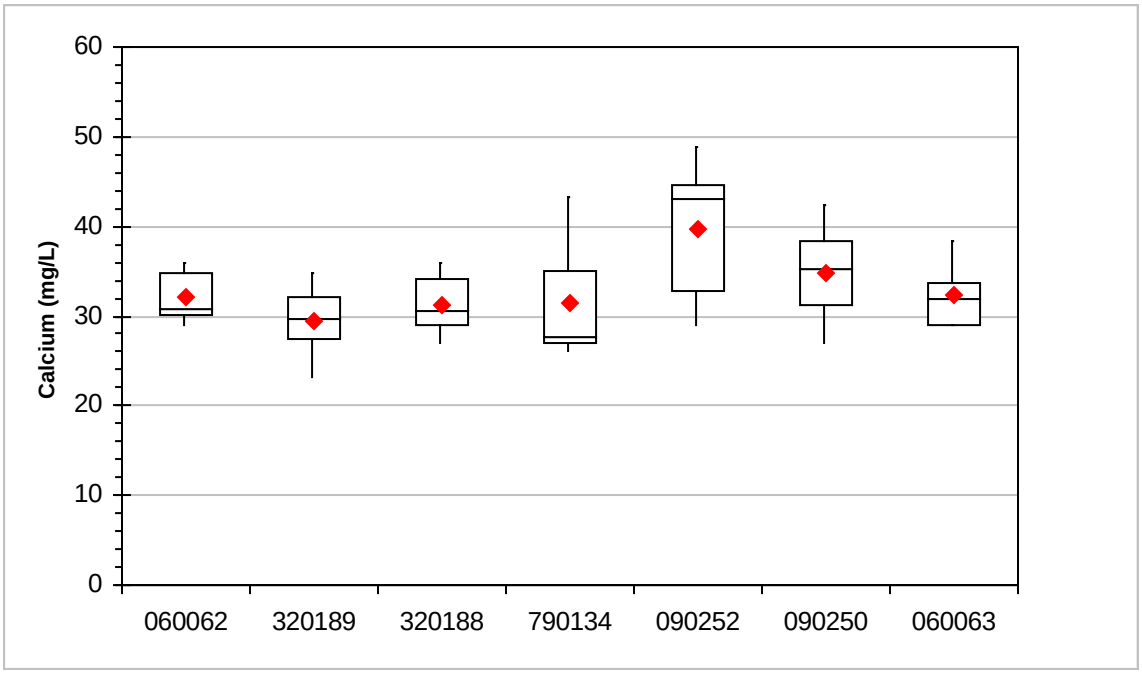


FIGURE 17. BOX PLOT OF MAGNESIUM CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

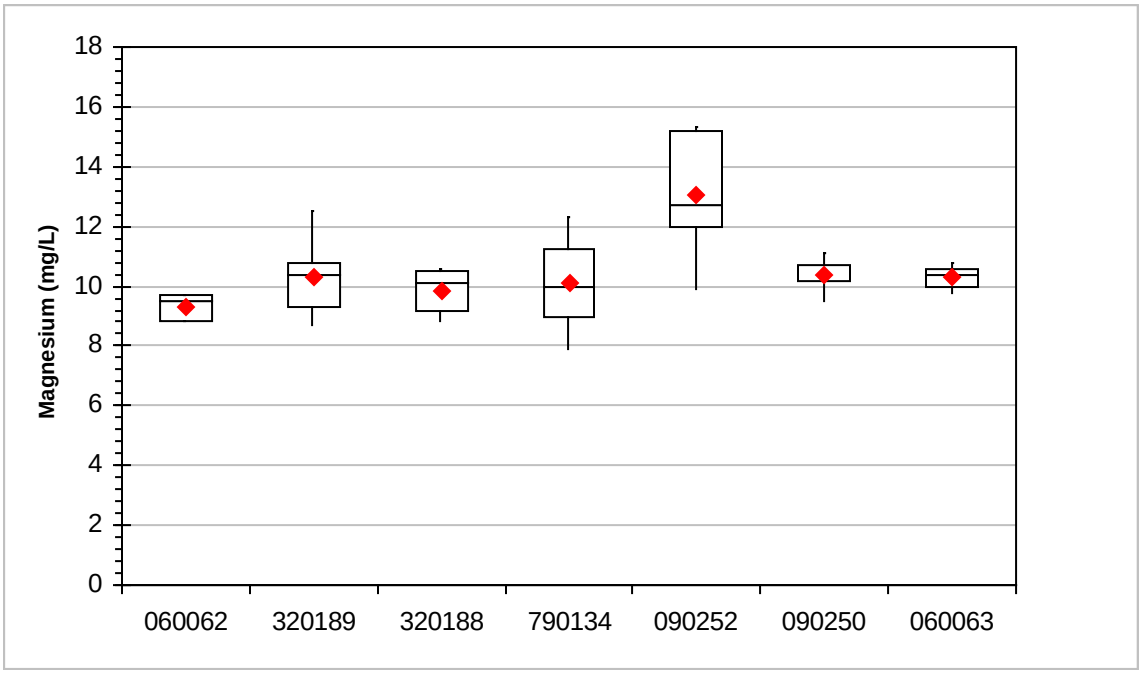


FIGURE 18. BOX PLOT OF SULFATE CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

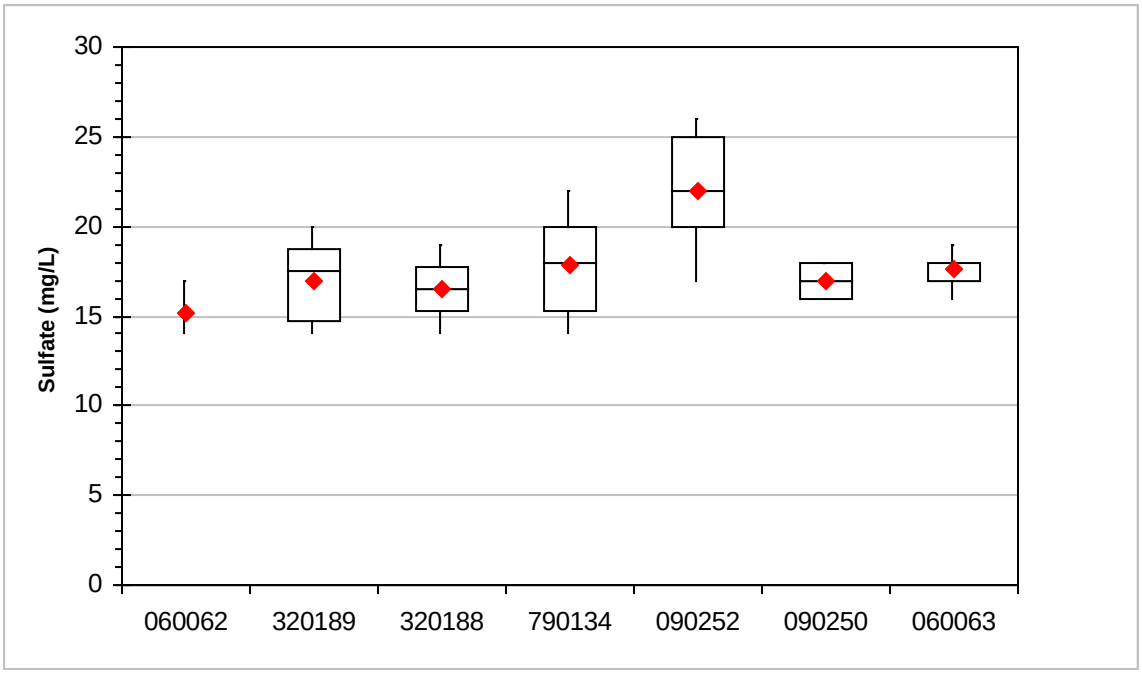


FIGURE 19. BOX PLOT OF CHLORIDE CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

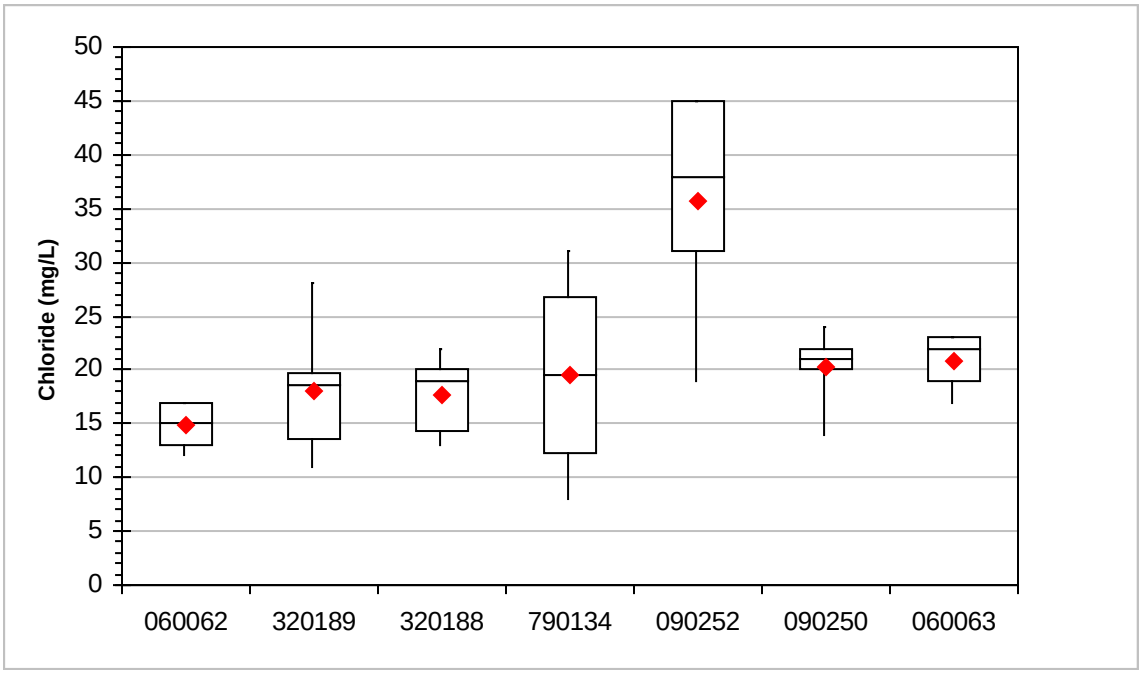


FIGURE 20. BOX PLOT OF CONDUCTANCE IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

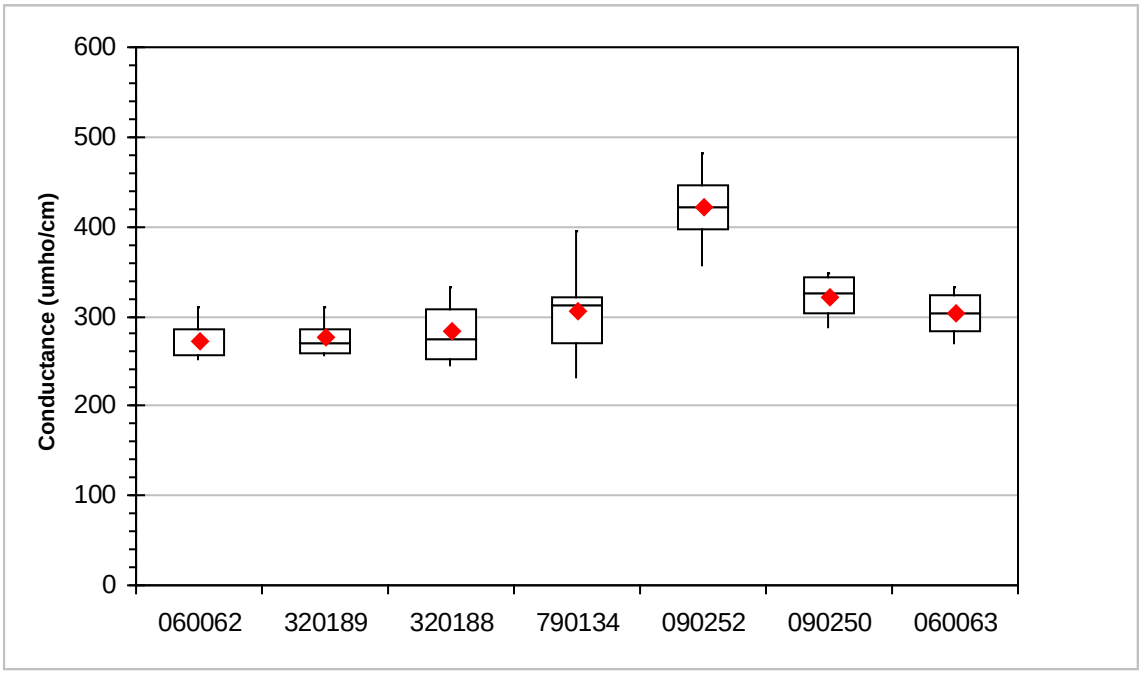


FIGURE 21. BOX PLOT OF POTASSIUM CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

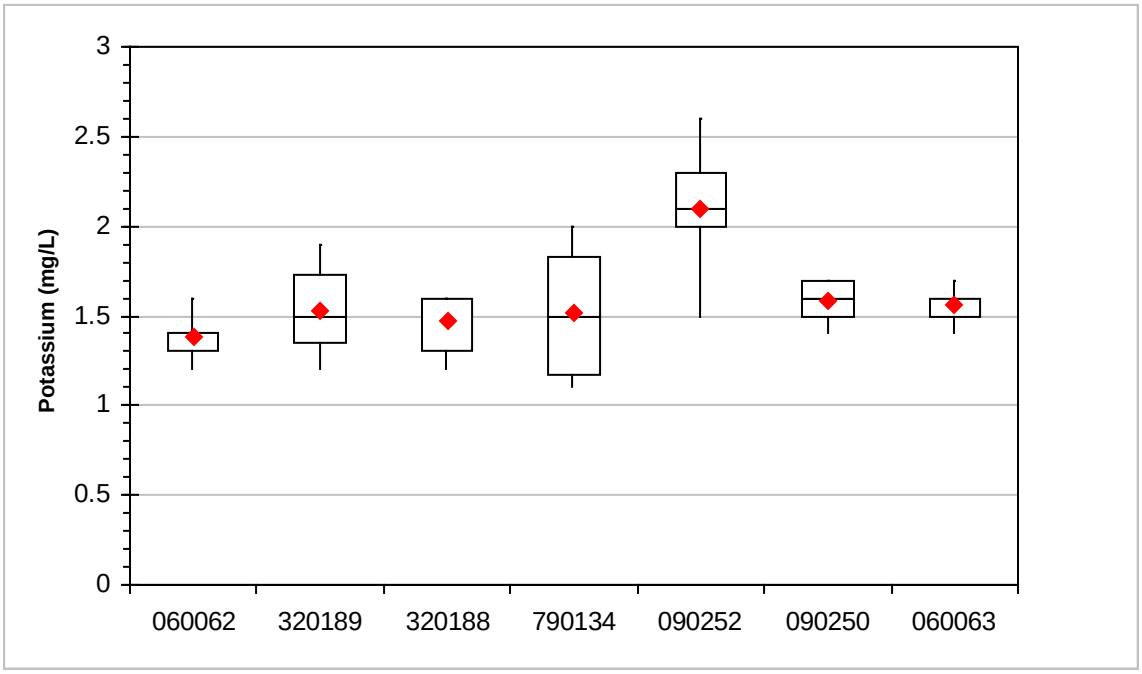


FIGURE 22. BOX PLOT OF SODIUM CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

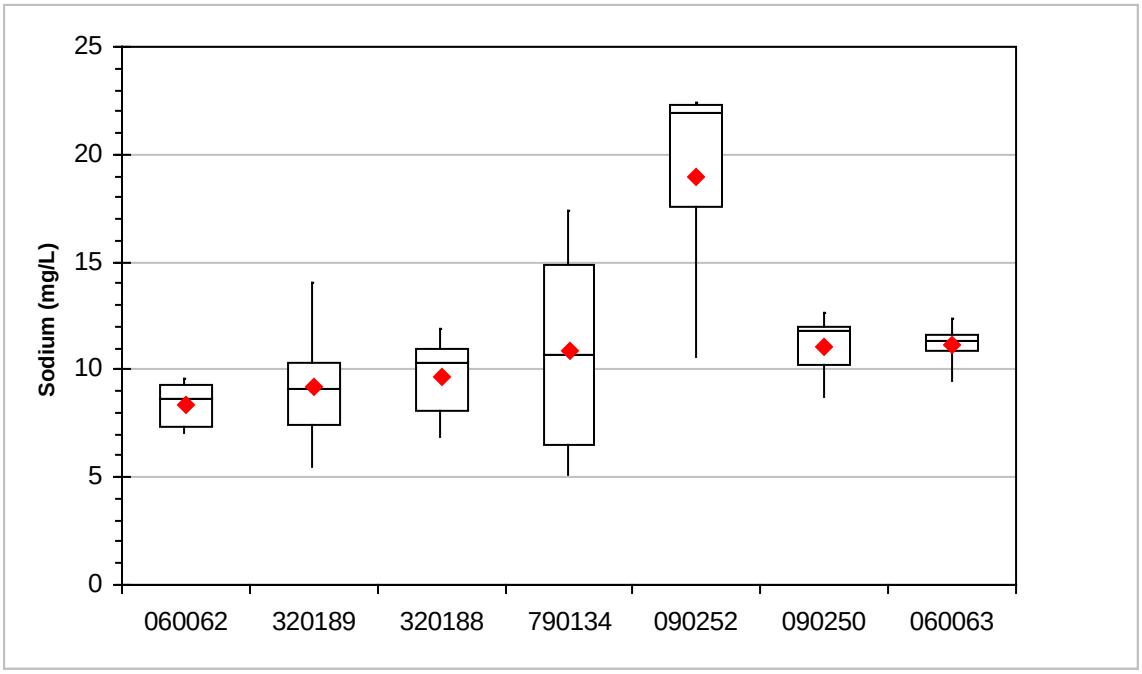


FIGURE 23. BOX PLOT OF TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

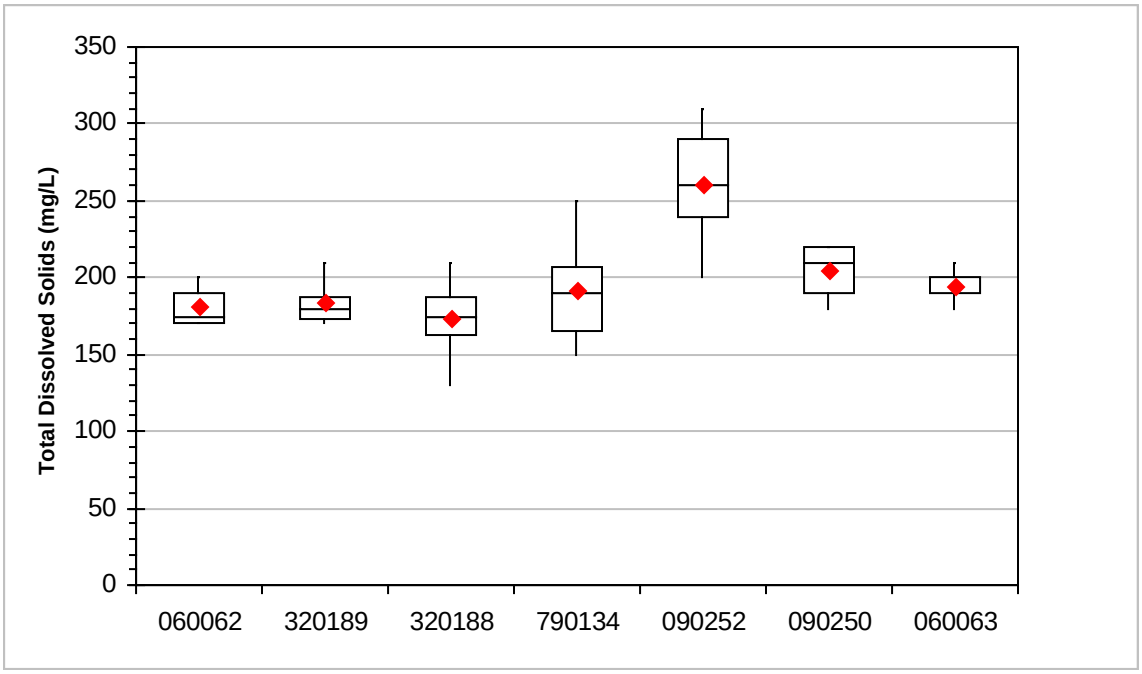


FIGURE 24. BOX PLOT OF TOTAL SUSPENDED SOLIDS CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

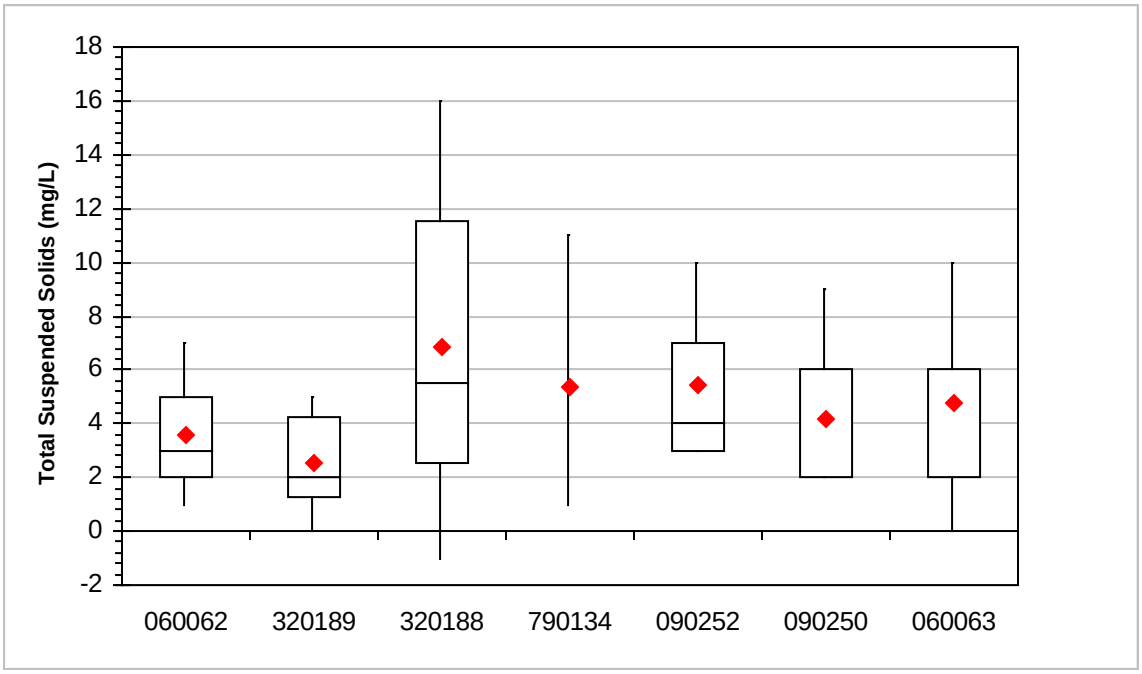


FIGURE 25. BOX PLOT OF TOTAL ORGANIC CARBON CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

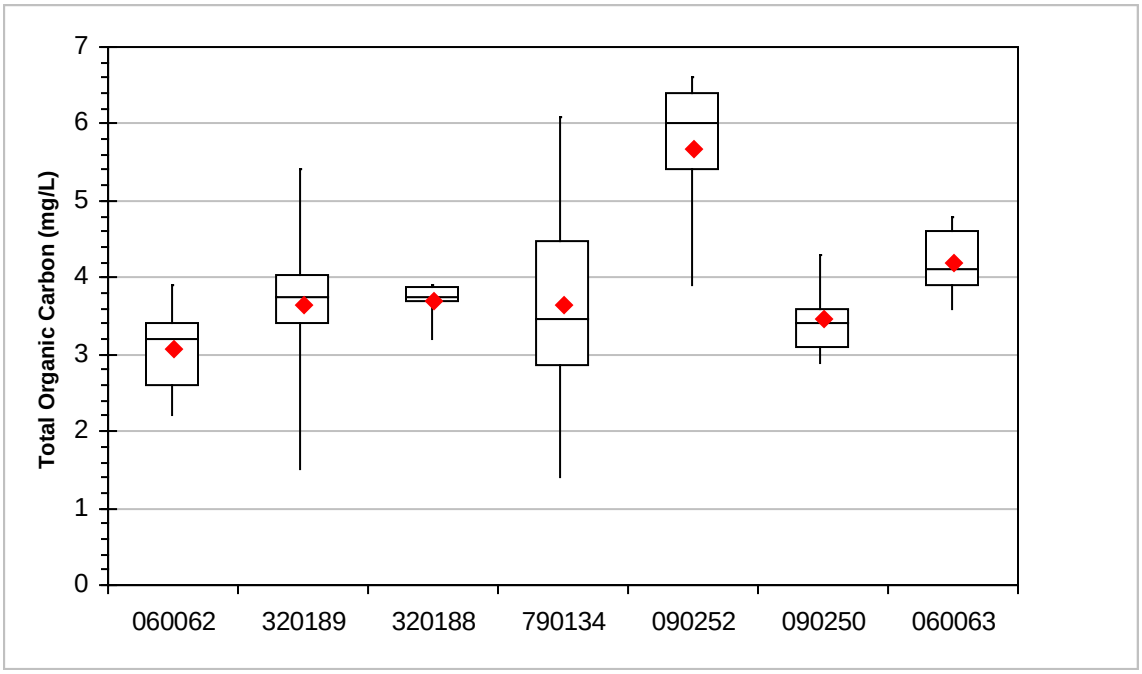


FIGURE 26. BOX PLOT OF TURBIDITY IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

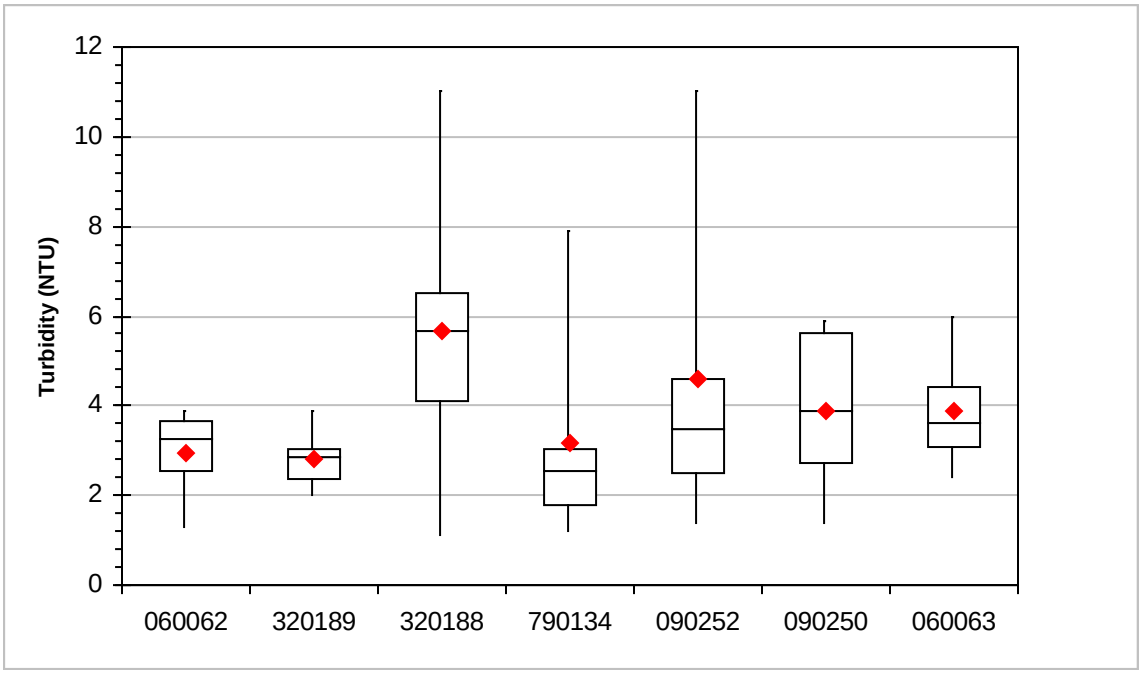


FIGURE 27. BOX PLOT OF CADMIUM CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

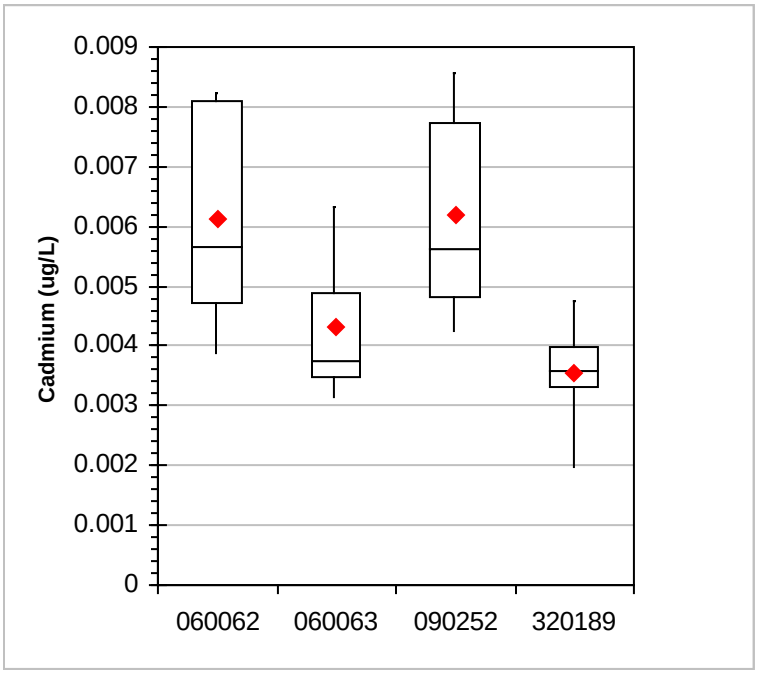


FIGURE 28. BOX PLOT OF CHROMIUM CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

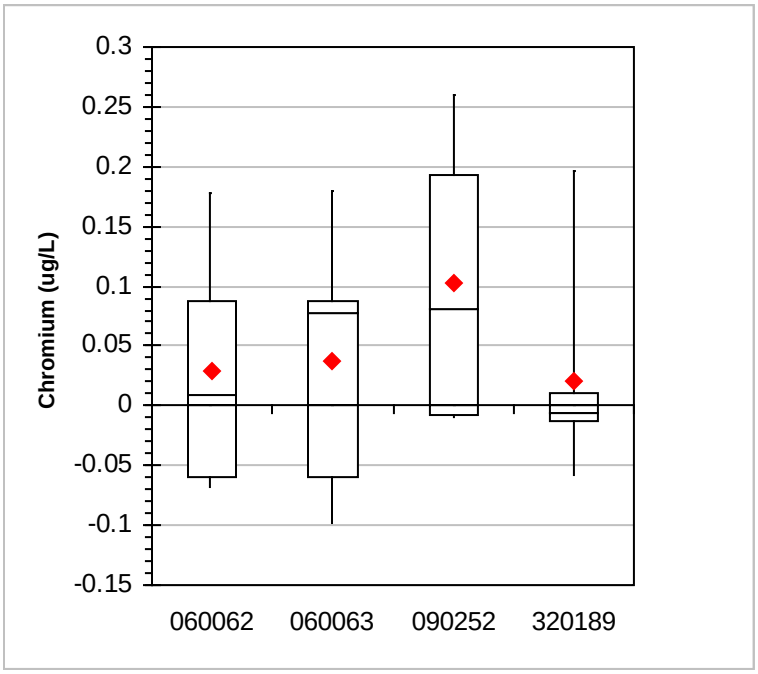


FIGURE 29. BOX PLOT OF LEAD CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

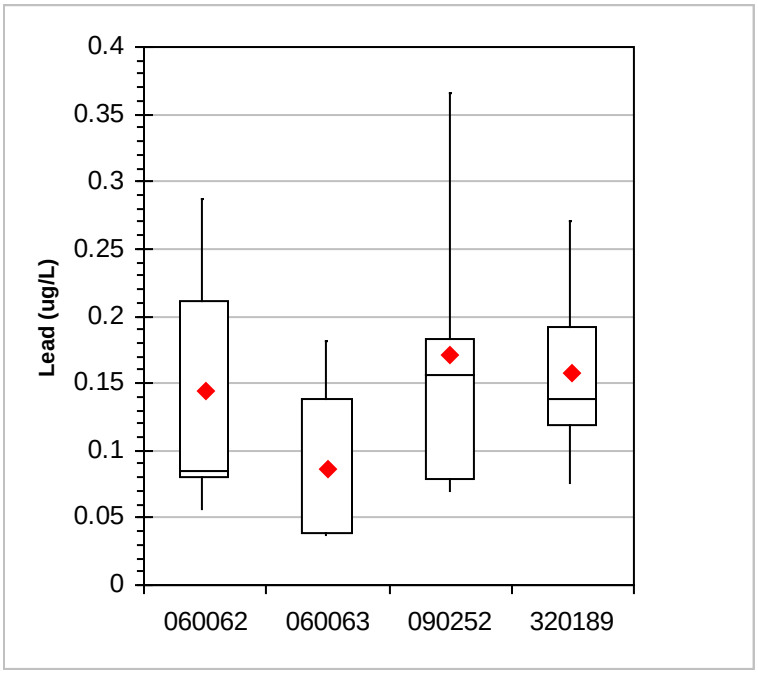


FIGURE 30. BOX PLOT OF COPPER CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

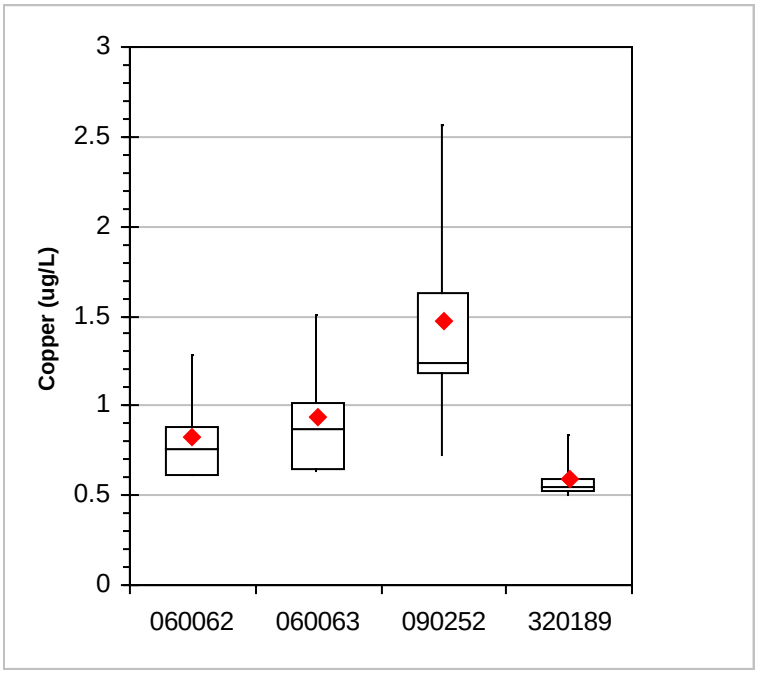


FIGURE 31. BOX PLOT OF NICKEL CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

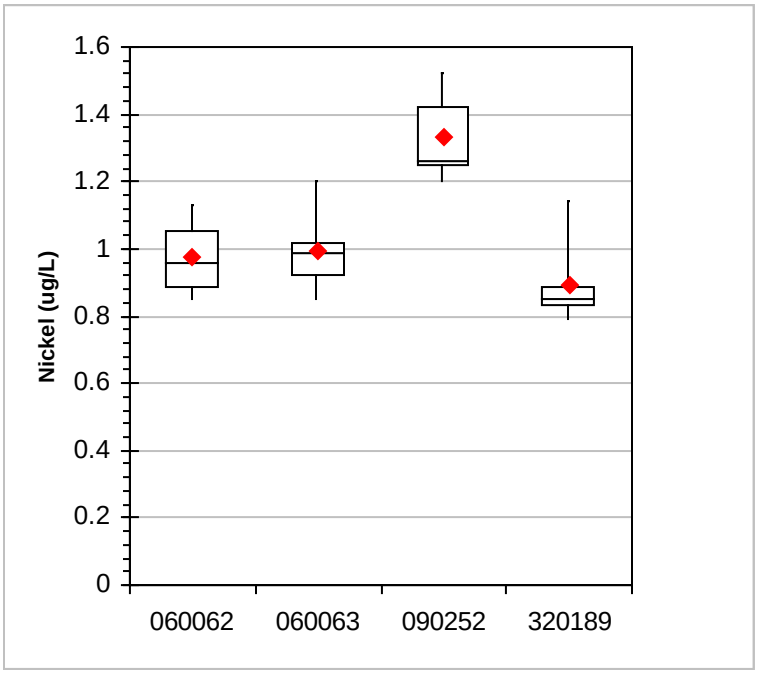


FIGURE 32. BOX PLOT OF ZINC CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

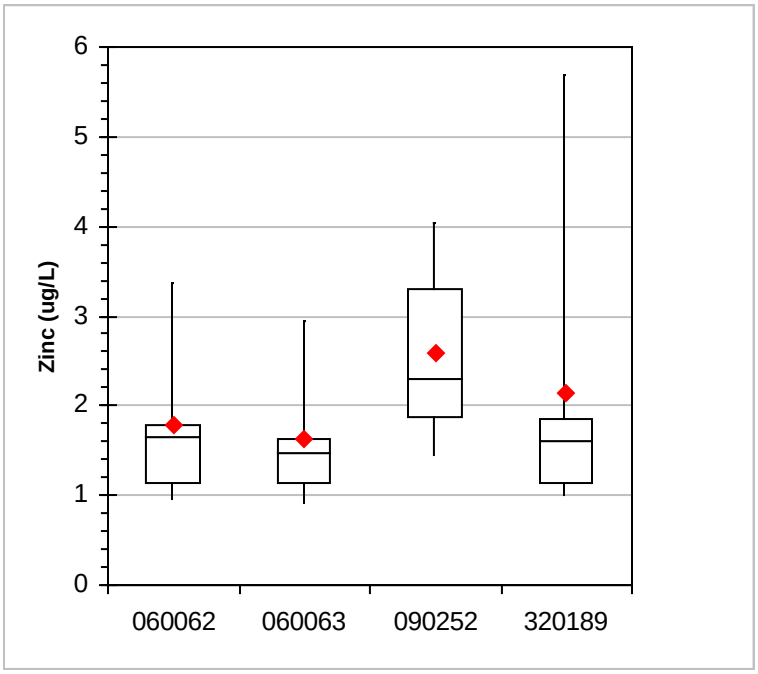


FIGURE 33. BOX PLOT OF MERCURY CONCENTRATIONS IN SAGINAW BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

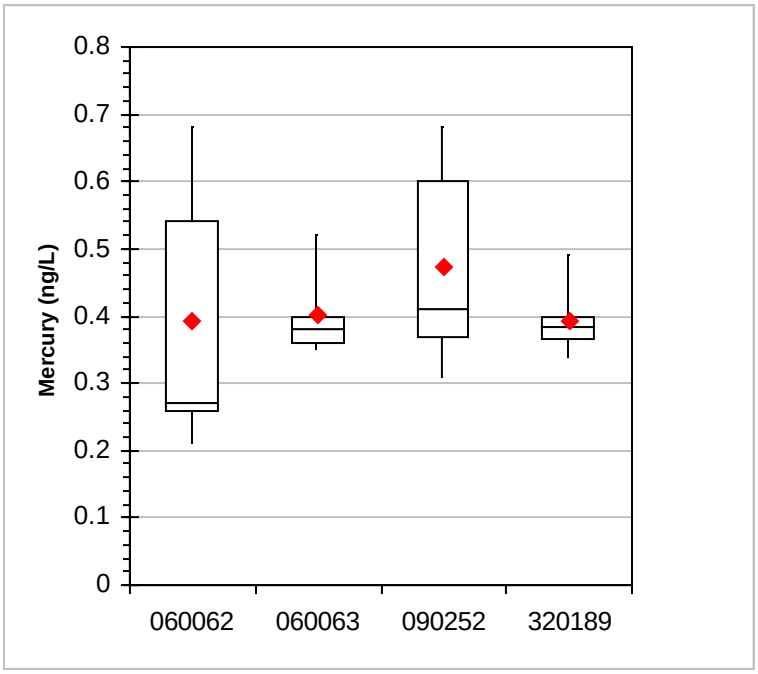


FIGURE 34. BOX PLOT OF AMMONIA CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

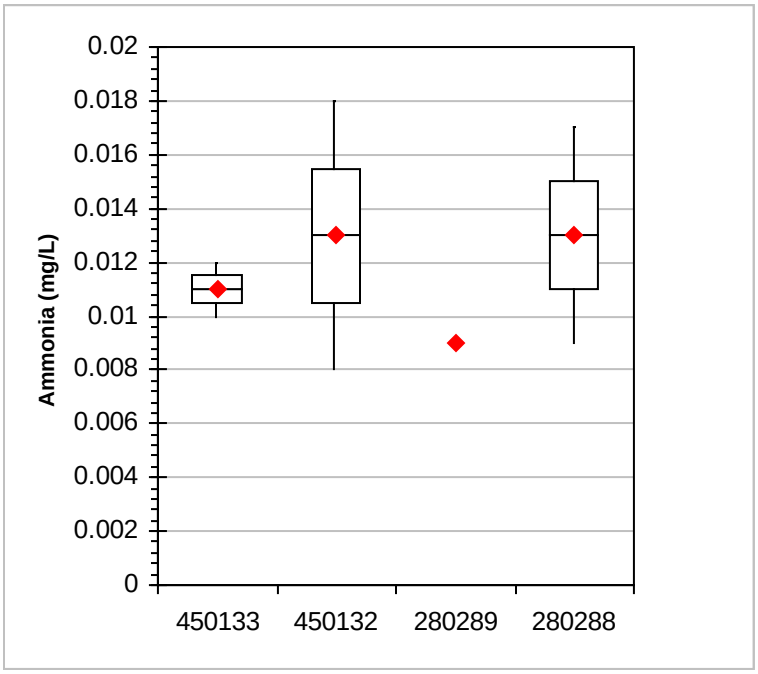


FIGURE 35. BOX PLOT OF CHLOROPHYLL *A* CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

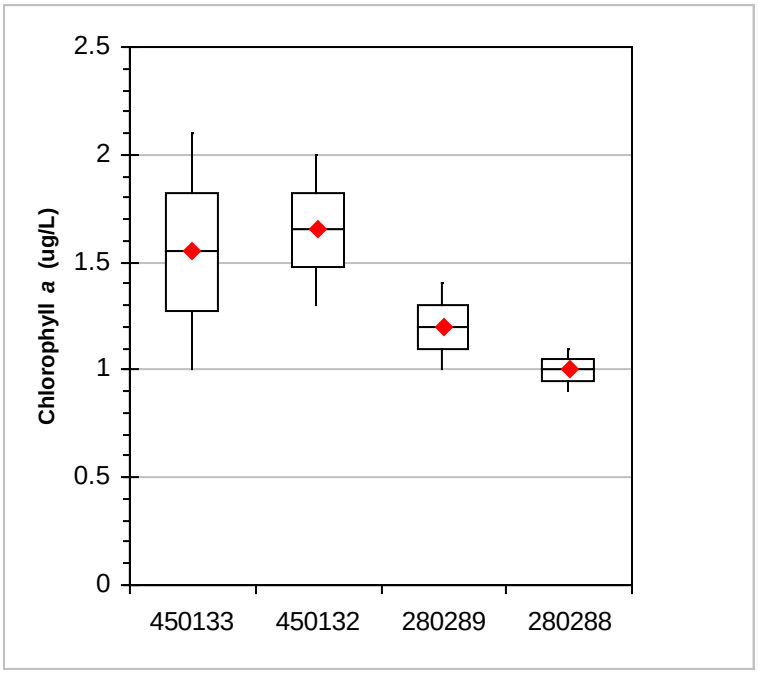


FIGURE 36. BOX PLOT OF TEMPERATURE IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

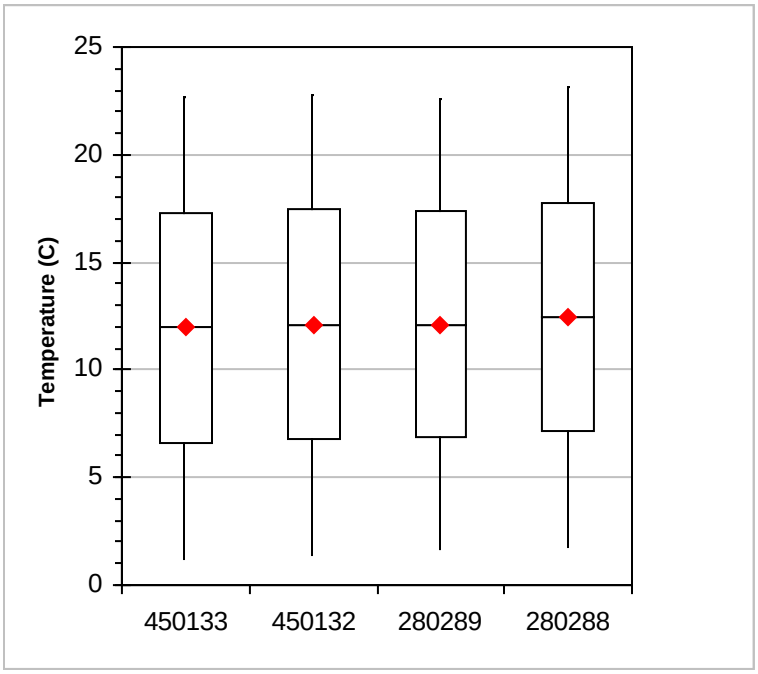


FIGURE 37. BOX PLOT OF DISSOLVED OXYGEN CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

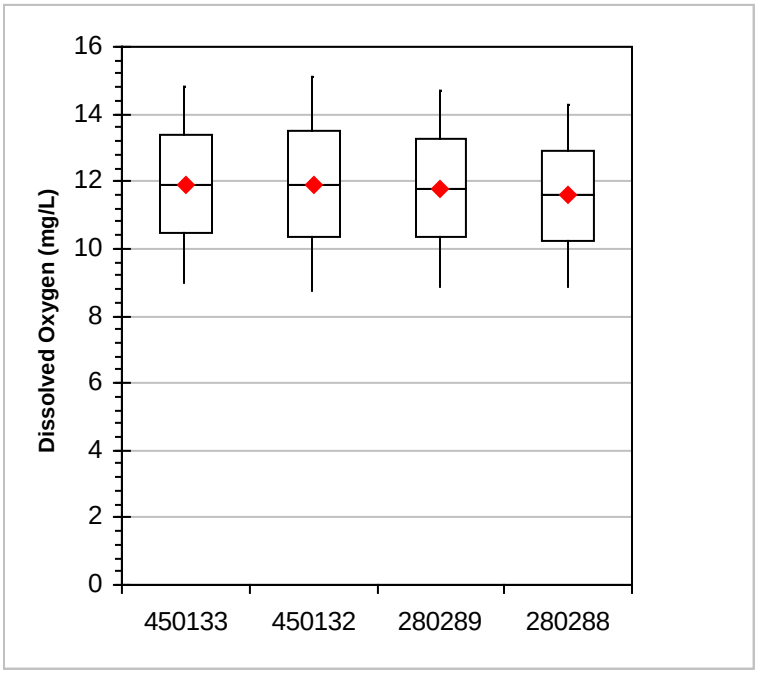


FIGURE 38. BOX PLOT OF NITRATE CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

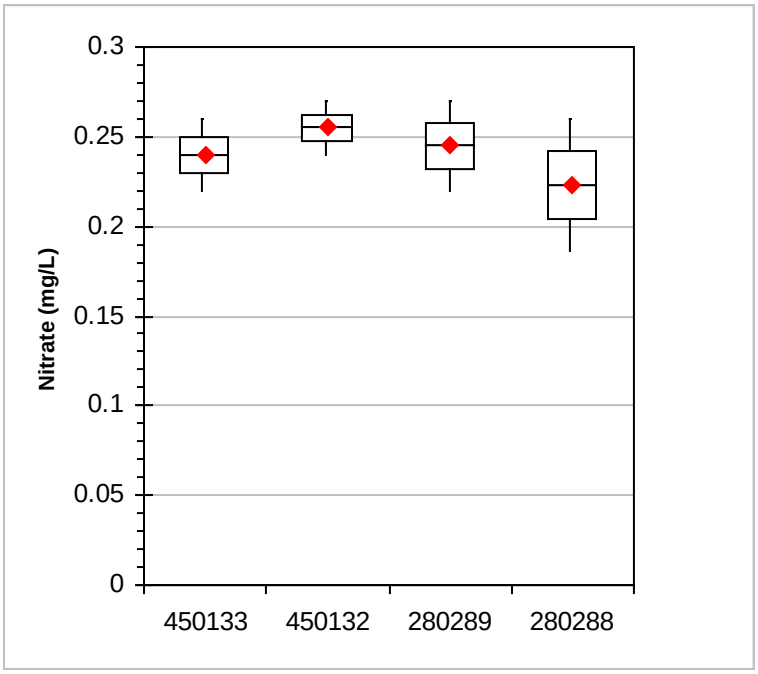


FIGURE 39. BOX PLOT OF NITRITE CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

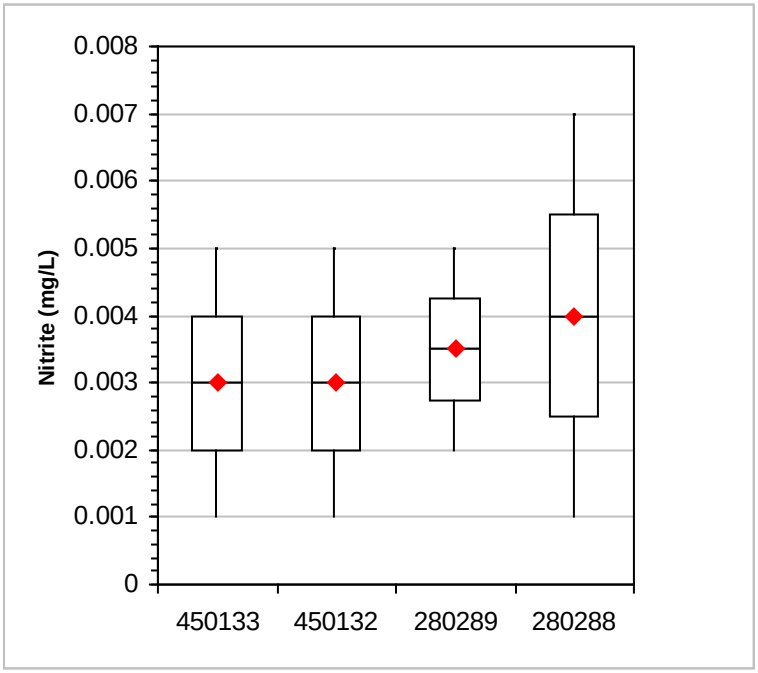


FIGURE 40. BOX PLOT OF PH IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

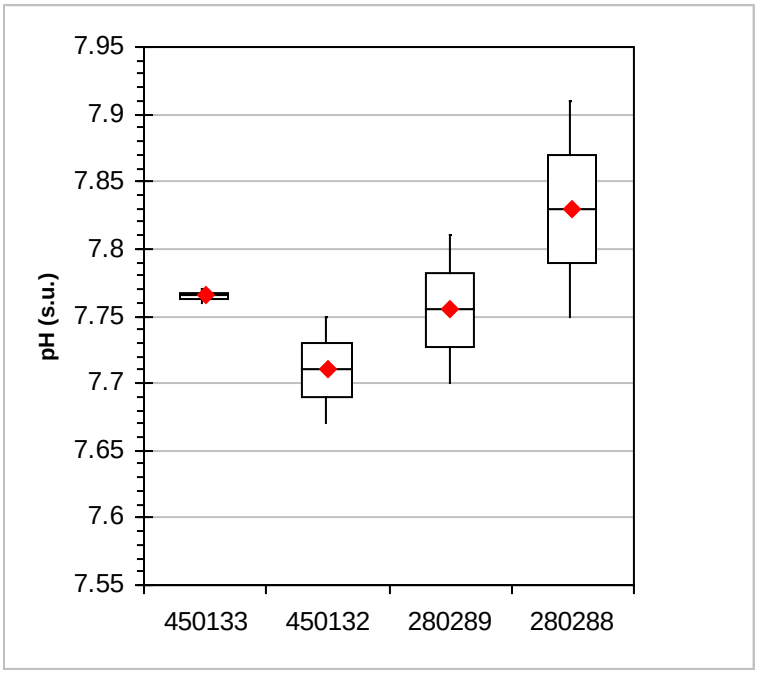


FIGURE 41. BOX PLOT OF SECCHI DISK TRANSPARENCY DEPTH IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

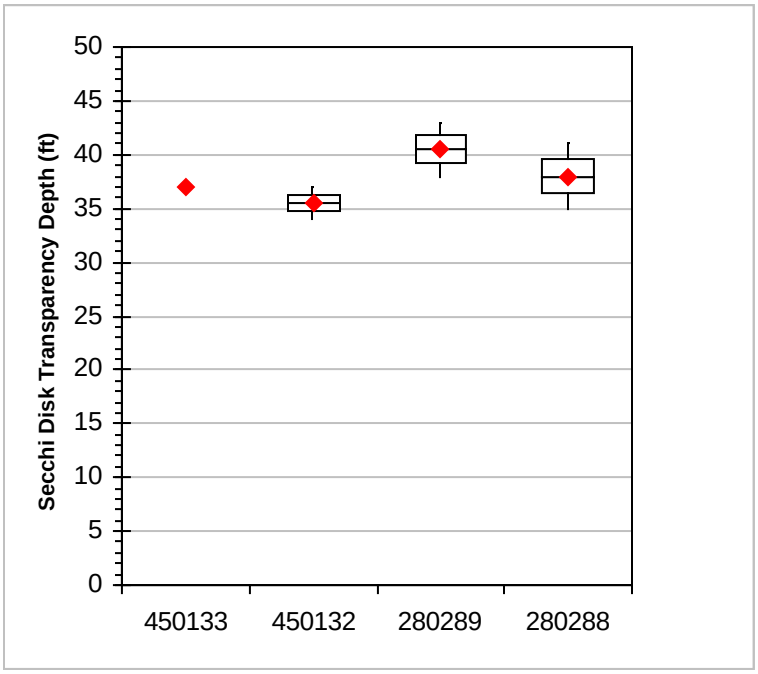


FIGURE 42. BOX PLOT OF TOTAL KJELDAHL NITROGEN CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

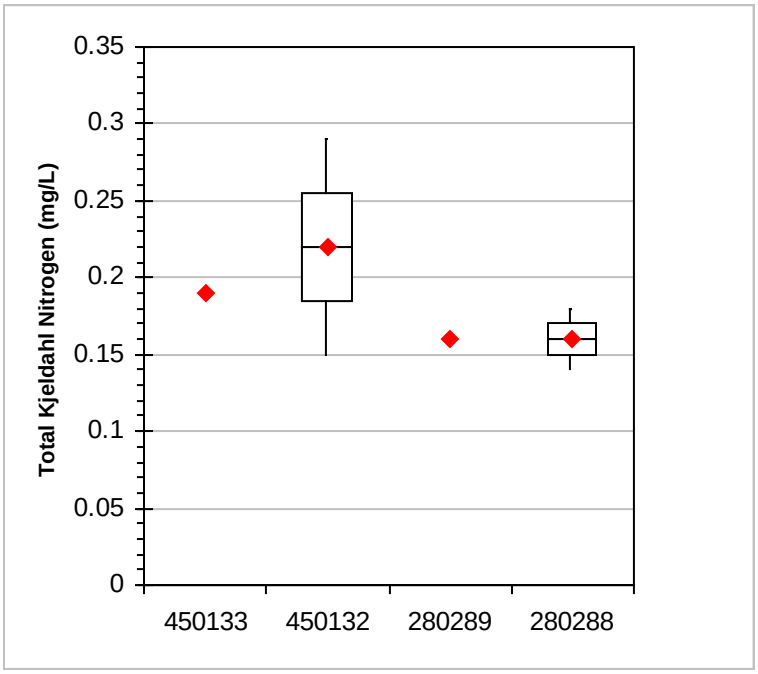


FIGURE 43. BOX PLOT OF ORTHOPHOSPHATE CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. MEAN CONCENTRATIONS ARE SHOWN AS A DIAMONDS (THERE WAS NO VARIABILITY IN THE DATA).

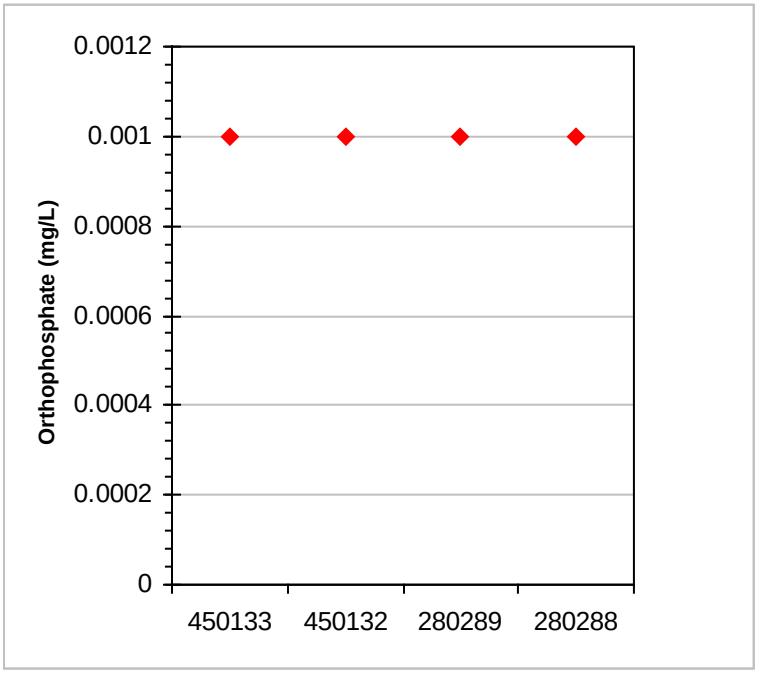


FIGURE 44. BOX PLOT OF TOTAL PHOSPHORUS CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

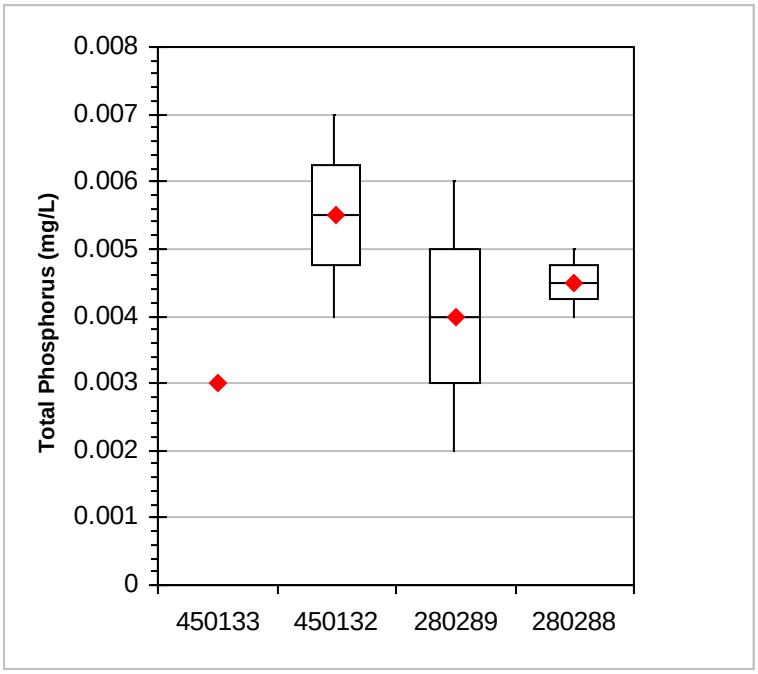


FIGURE 45. BOX PLOT OF HARDNESS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

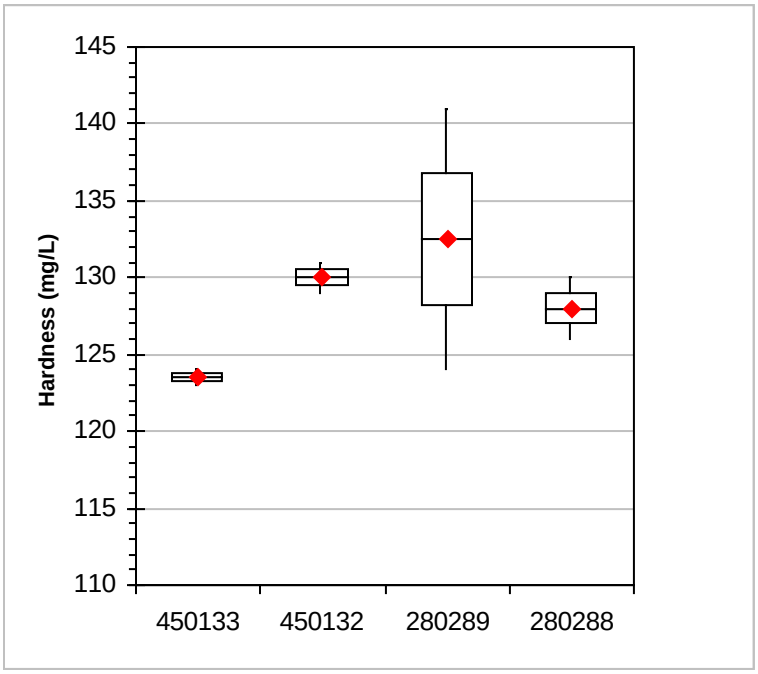


FIGURE 46. BOX PLOT OF ALKALINITY IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

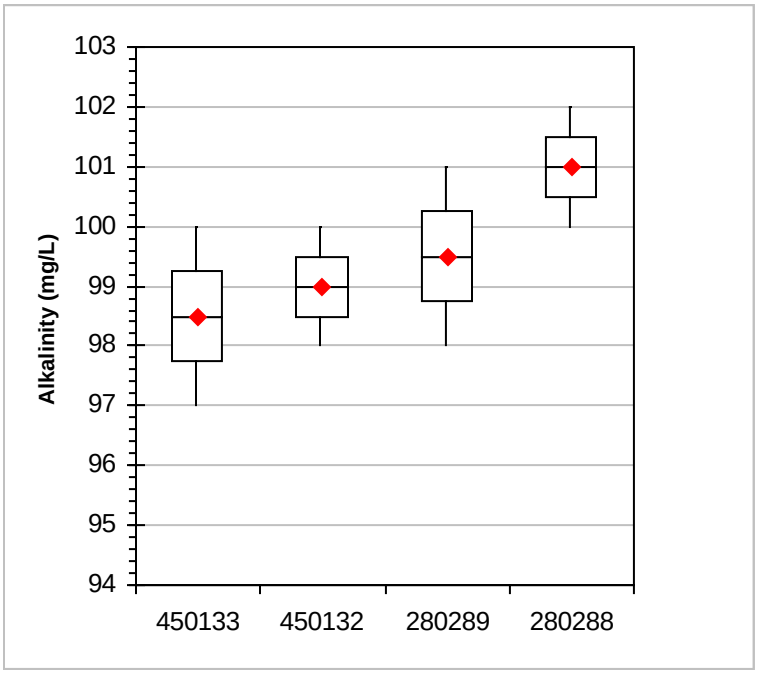


FIGURE 47. BOX PLOT OF CALCIUM CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

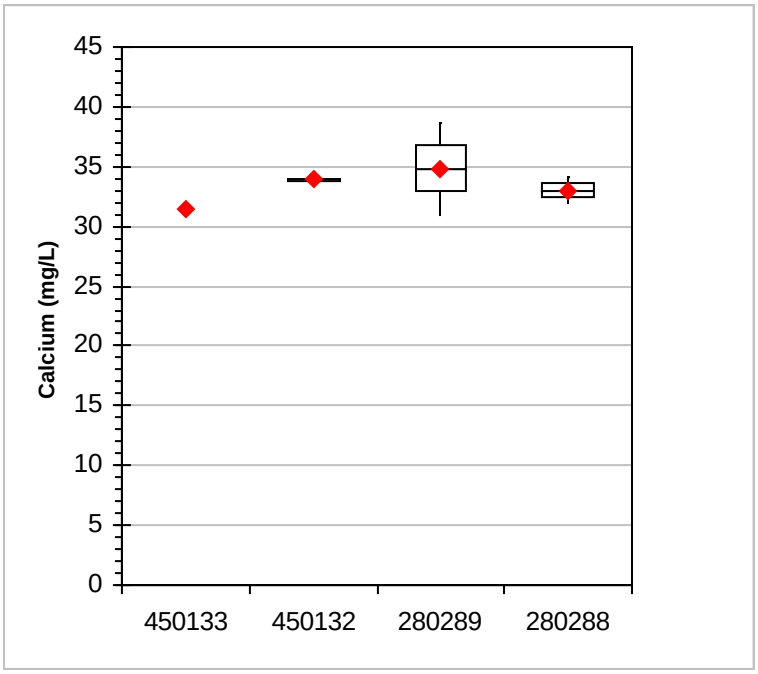


FIGURE 48. BOX PLOT OF MAGNESIUM CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

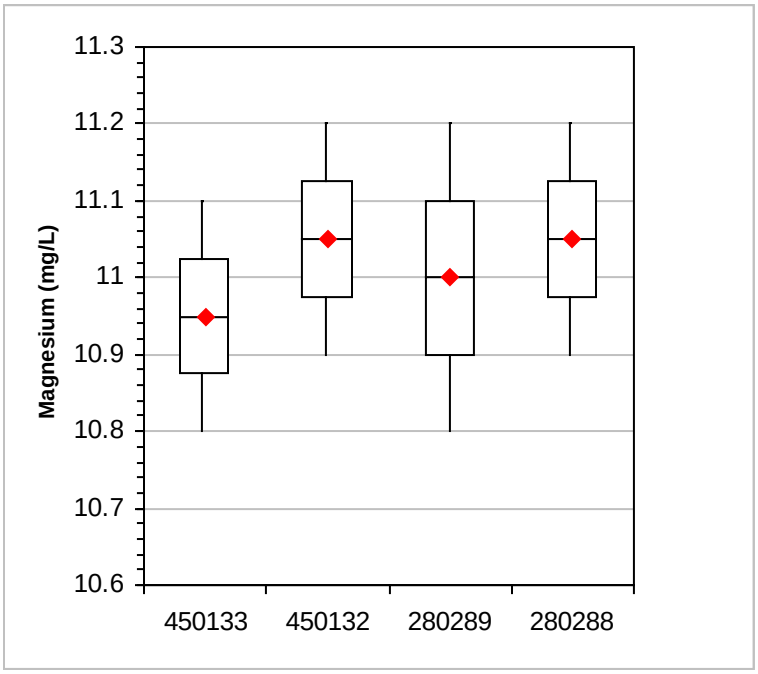


FIGURE 49. BOX PLOT OF SULFATE CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

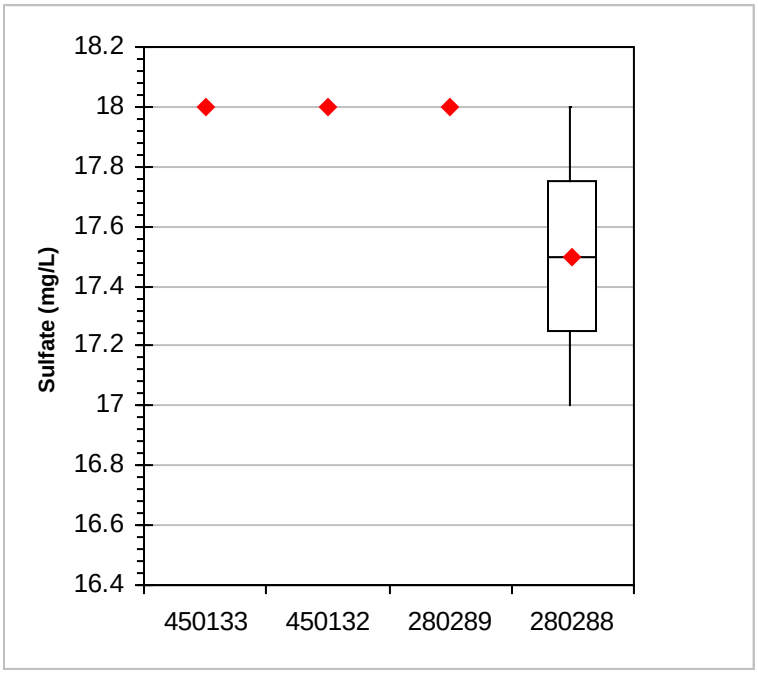


FIGURE 50. BOX PLOT OF CHLORIDE IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

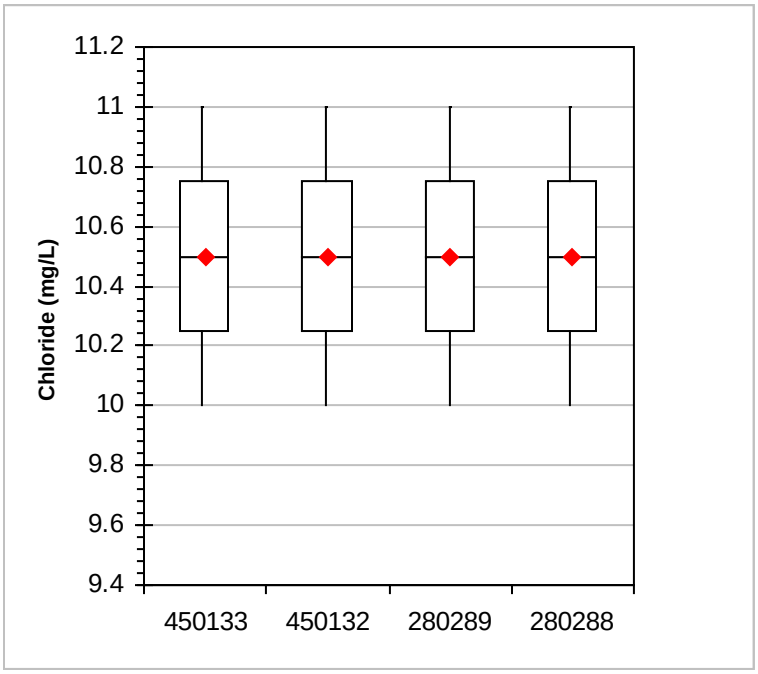


FIGURE 51. BOX PLOT OF CONDUCTANCE IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

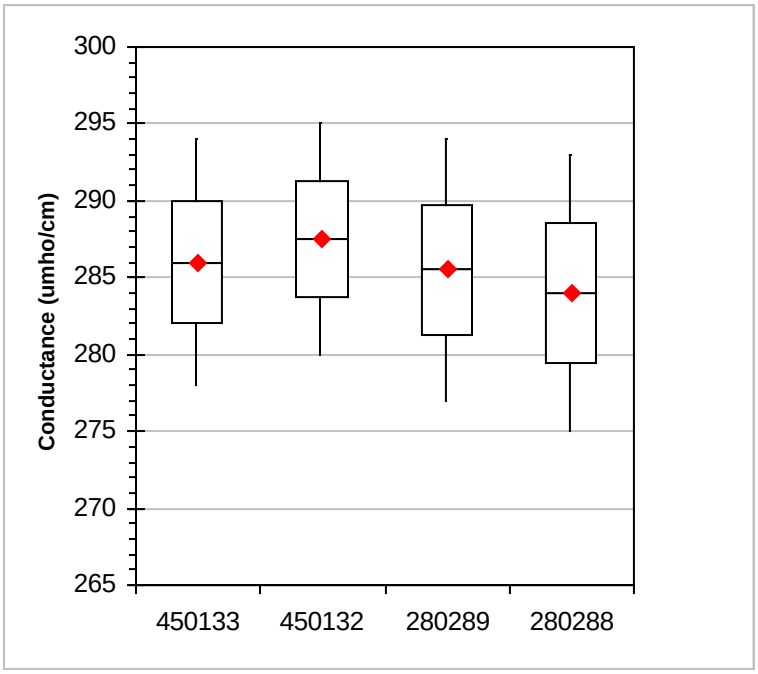


FIGURE 52. BOX PLOT OF POTASSIUM CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

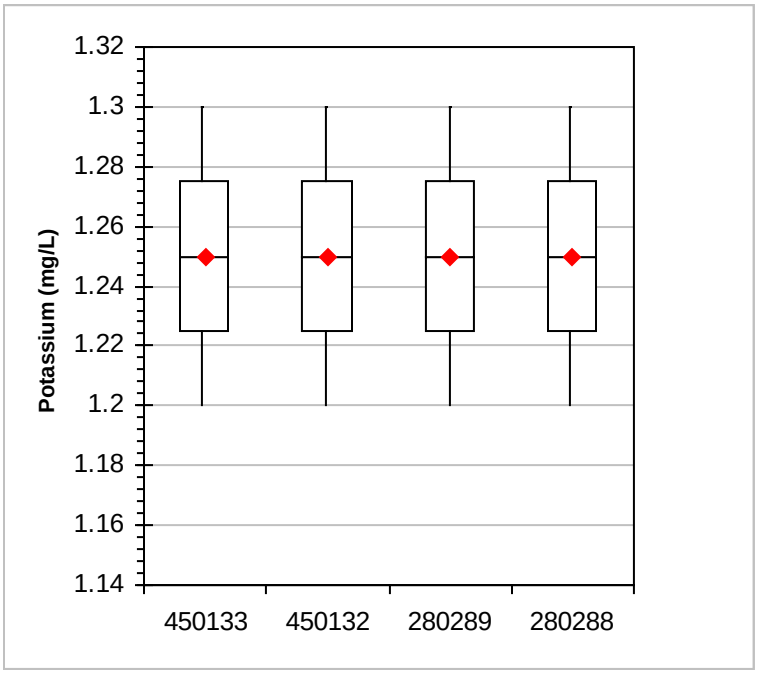


FIGURE 53. BOX PLOT OF SODIUM CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.

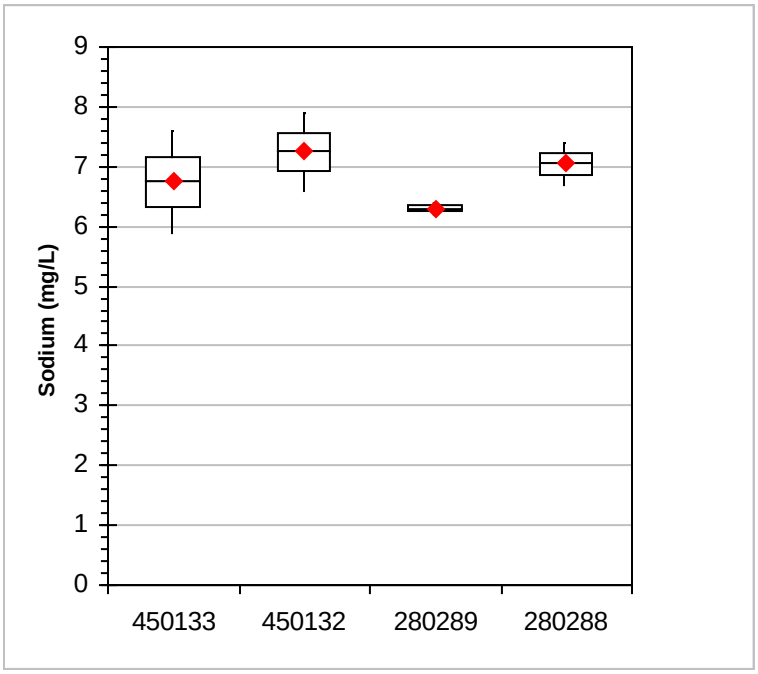


FIGURE 54. BOX PLOT OF TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. MEAN CONCENTRATIONS ARE SHOWN AS A DIAMONDS (THERE WAS NO VARIABILITY IN THE DATA).

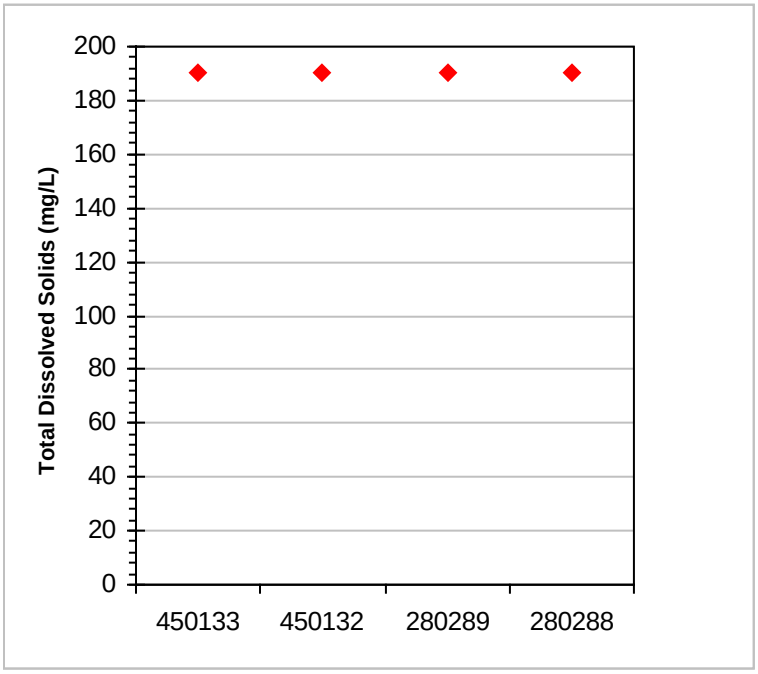
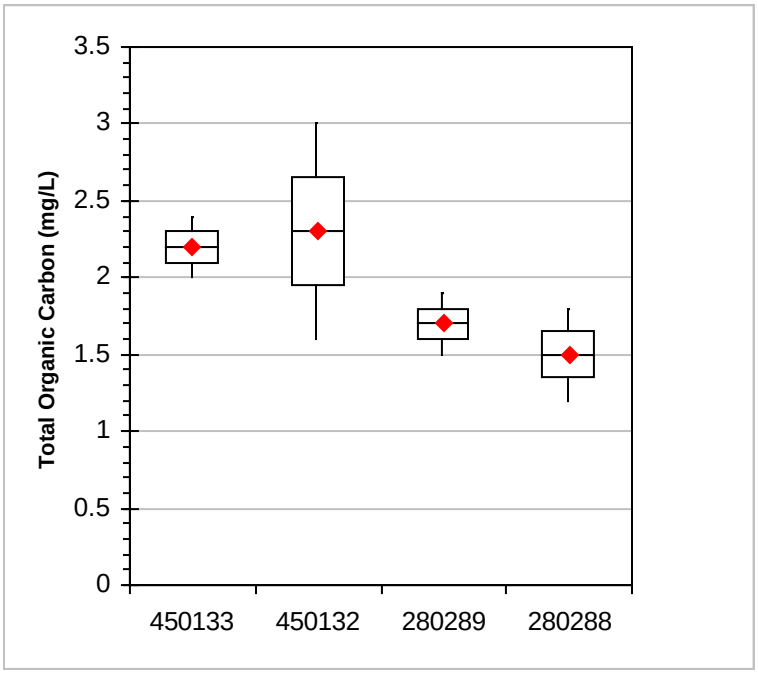


FIGURE 55. BOX PLOT OF TOTAL ORGANIC CARBON CONCENTRATIONS IN GRAND TRAVERSE BAY DURING 2005. EACH BOX EXHIBITS THE INNER QUARTILES, THE WHISKERS EXHIBIT THE OUTER QUARTILES, THE MEDIAN IS SHOWN AS A SOLID LINE AND THE MEAN IS SHOWN AS A DIAMOND.



TABLES

TABLE 1. SAMPLING DATES FOR SELECTED PARAMETERS IN SAGINAW BAY AND GRAND TRAVERSE BAY.

Saginaw Bay		**060062**	**060078**	**320189**	**320188**	**790134**	**090252**	**090250**	**060063**
Sampling Date	May 9, 2005	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals
	June 7, 2005	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals
	July 11, 2005	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals
	September 19, 2005	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals
	October 12, 2005		Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ			
	November 2, 2005	Conventional Limnological In situ Metals	Conventional Limnological In situ	Conventional Limnological In situ Metals	Conventional Limnological	Conventional Limnological	Conventional Limnological Metals	Conventional Limnological	Conventional Limnological Metals
Grand Traverse Bay		**450132**	**450133**	**280288**	**280289**				
Sampling Date	April 5, 2005	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ				
	August 3, 2005	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ	Conventional Limnological In situ				

TABLE 2. PARAMETERS ANALYZED IN SAMPLES COLLECTED IN SAGINAW BAY AND GRAND TRAVERSE BAY AT SELECTED STATIONS.

CONVENTIONAL PARAMETERS	**TRACE METALS AND MERCURY**
Total Alkalinity Calcium - Total Chloride - Total Conductivity Hardness - Calculated Magnesium - Total Potassium - Total Sodium - Total Sulfate (SO_4) - Total Totals Dissolved Solids (TDS) - Calculated Total Organic Carbon Total Suspended Solids (TSS) Turbidity	Cadmium Copper Chromium Lead Nickel Zinc Mercury
LIMNOLOGICAL PARAMETERS	
Ammonia (NH_3-N) – Total Chlorophyll *a* Dissolved Oxygen Nitrate-N (NO_3+NO_2) - (NO_2) Calculated Nitrite-N (NO_2-N) pH Secchi Disk Reading (Light transparency measurement) Temperature Total Kjeldahl Nitrogen Total Orthophosphate Total Phosphorus	

TABLE 3. LABORATORY QUANTIFICATION AND DETECTION LEVELS FOR TRACE METALS AND MERCURY ANALYSES.

Analyte	Detection Level	Quantification Level	Units
Hg	0.14	0.45	ng/L
Cd	0.011	0.037	ug/L
Cr	0.057	0.19	ug/L
Cu	0.03	0.1	ug/L
Pb	0.0041	0.014	ug/L
Ni	0.093	0.31	ug/L
Zn	0.13	0.43	ug/L

TABLE 4. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 060062.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	3.2	1.3	3.8	15.0	7.6	6.2	3.8	5.4
Conductivity	umho/cm	311	286	257	257	253	273	257	25
Dissolved Oxygen	mg/L	12.57	8.94	9.28	8.35	10.61	9.95	9.28	1.68
Hardness ($CaCO_3$)	mg/L	130	127	113	114	108	118	114	10
pH	pH	7.67	7.95	7.88	7.75	7.21	7.69	7.75	0.29
Secchi Disk reading	feet	9.5	14.0	16.0	5.0	4.0	9.7	9.5	5.3
Temperature	^oC	9.21	18.33	21.51	21.02	10.02	16.02	18.33	5.98
Total Alkalinity	mg/L	88	94	84	80	79	85	84	6
Total Ammonia	mg N/L	0.004 T	0.011 T	0.006 T	0.004 T	0.023	0.010	0.006	0.008
Total Calcium	mg/L	35.9	34.9	30.8	30.2	28.9	32.1	30.8	3.1
Total Chloride	mg/L	17	17	13	15	12	15	15	2
Total Dissolved Solids	mg/L	200	190	175	170	170	181	175	13
Total Kjeldahl Nitrogen	mg N/L	0.28	0.26	0.25	0.40	0.32	0.30	0.28	0.06
Total Magnesium	mg/L	9.7	9.7	8.8	9.5	8.8	9.3	9.5	0.5
Total Nitrate	mg N/L	0.500	0.380	0.230	0.002 W	0.103	0.243	0.230	0.202
Total Nitrite	mg N/L	0.003	0.004	0.004	0.001 T	0.002 T	0.003	0.003	0.001
Total Organic Carbon	mg/L	3.9	3.4	2.2	3.2	2.6	3.1	3.2	0.7
Total Ortho Phosphate	mg P/L	0.003	ND W	ND W	0.002 T	0.002 T	0.002	0.002	0.001
Total Phosphorus	mg P/L	0.009	0.008	0.011	0.023	0.017	0.014	0.011	0.006
Total Potassium	mg/L	1.4	1.6	1.3	1.4	1.2	1.4	1.4	0.1
Total Sodium	mg/L	9.6	9.3	7.1	8.6	7.3	8.4	8.6	1.1
Total Sulfate	mg/L	15	17	14	15	15	15	15	1
Total Suspended Solids	mg/L	2 ND	3 ND	1 ND	5 A	7	4	3	2
Turbidity	NTU	1.3 ND	ND	ND	3.9	3.6	2.9	3.6	1.4

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
C = Value caclulated from other independent parameters.
D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
E = Result is estimated due to high recovery of batch QC.
G = Result and RL are estimated due to initial calibration standard criteria failure.
H and HT = Recommended laboratory holding time was exceeded.
I and DM = Dilution required due to matrix interference; reporting limit raised.
ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 5. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 320189.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	10/12/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	7.7	3.4	5.1	7.8	5.8	12.0	7.0	6.8	3.0
Conductivity	umho/cm	274	257	257	309	268	290	276	271	20
Dissolved Oxygen	mg/L	11.37	7.45	9.51	8.79	10.51	11.05	9.78	10.01	1.49
Hardness ($CaCO_3$)	mg/L	123	118	101	120	112	124	116	119	9
pH	pH	7.91	8.24	8.49	7.95	7.77	7.44	7.97	7.93	0.37
Secchi Disk reading	feet	5.3	6.0	6.9	4.8	3.9	4.0	5.2	5.1	1.2
Temperature	^{o}C	12.37	21.72	24.60	20.37	12.51	8.50	16.68	16.44	6.40
Total Alkalinity	mg/L	86	85	71	82	79	84	81	83	6
Total Ammonia	mg N/L	0.011	0.014	0.008 T	0.011	0.008 T	0.019	0.012	0.011	0.004
Total Calcium	mg/L	34.9	32.3	23.3	27.3	27.7	31.6	29.5	29.7	4.2
Total Chloride	mg/L	11	12	19	28	18	20	18	19	6
Total Dissolved Solids	mg/L	180	170	170	210	180	190	183	180	15
Total Kjeldahl Nitrogen	mg N/L	0.31	0.25	0.43	0.60	0.39	0.51	0.42	0.41	0.13
Total Magnesium	mg/L	8.7	9.0	10.4	12.5	10.3	10.9	10.3	10.4	1.4
Total Nitrate	mg N/L	0.400	0.210	0.132	ND W	0.010	0.030	0.156	0.132	0.158
Total Nitrite	mg N/L	0.007	0.004	0.008	0.002	0.002	0.001 T	0.004	0.003	0.003
Total Organic Carbon	mg/L	3.3	1.5	3.7	5.4	4.1	3.8	3.6	3.8	1.3
Total Ortho Phosphate	mg P/L	0.004	ND W	0.001 T	0.002 T	ND W	0.001 T	0.002	0.002	0.001
Total Phosphorus	mg P/L	0.010	0.009	0.013	0.017	0.014	0.016	0.013	0.014	0.003
Total Potassium	mg/L	1.3	1.2	1.5	1.9	1.5	1.8	1.5	1.5	0.3
Total Sodium	mg/L	5.5	7.1	8.6	14.0	9.6	10.6	9.2	9.1	3.0
Total Sulfate	mg/L	14	14	17	19	20	18	17	18	3
Total Suspended Solids	mg/L	5	2 ND	0 ND	2 ND	1 ND	5	3	2	2
Turbidity	NTU	2.0	ND	2.2	2.9	3.1	3.9	2.8	2.9	0.8

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
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D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
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ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
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M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 6. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 320188.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	10/12/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	2.2	1.1	3.9	6.0	9.9	8.2	5.2	5.0	3.4
Conductivity	umho/cm	308	333	251	245	275		282	275	38
Dissolved Oxygen	mg/L	12.04	7.82	9.74	8.90	9.75		9.65	9.74	1.55
Hardness ($CaCO_3$)	mg/L	129	133	113	108	111	118	119	116	10
pH	pH	7.99	8.05	8.24	8.31	8.03		8.12	8.05	0.14
Secchi Disk reading	feet	10.2	10.5	11.0	4.9	3.0	2.0	6.9	7.6	4.1
Temperature	^{o}C	11.76	20.15	23.84	20.73	14.18		18.13	20.15	4.99
Total Alkalinity	mg/L	96	97	83	75	77	85	86	84	9
Total Ammonia	mg N/L	0.008 T	0.022	0.004	0.002 T	0.005 T	0.009 T	0.008	0.007	0.007
Total Calcium	mg/L	35.2	35.8	30.9	28.5	27.0	30.1	31.3	30.5	3.6
Total Chloride	mg/L	18	22	13	13	20	20	18	19	4
Total Dissolved Solids	mg/L	130	210	170	160	180	190	173	175	27
Total Kjeldahl Nitrogen	mg N/L	0.26	0.29	0.32	0.34	0.55	0.57	0.39	0.33	0.14
Total Magnesium	mg/L	9.9	10.6	8.8	8.9	10.6	10.3	9.9	10.1	0.8
Total Nitrate	mg N/L	0.570	0.530	0.169	ND W	0.002 W	0.003 T	0.255	0.169	0.278
Total Nitrite	mg N/L	0.005	0.005	0.004	0.001 T	0.002	0.001 T	0.003	0.003	0.002
Total Organic Carbon	mg/L	3.8	3.9	3.2	3.7	3.9	3.7	3.7	3.8	0.3
Total Ortho Phosphate	mg P/L	0.003	ND W	ND W	0.002 T	0.001 T	0.004	0.003	0.003	0.001
Total Phosphorus	mg P/L	0.008	0.007	0.010	0.023	0.021	0.024	0.016	0.016	0.008
Total Potassium	mg/L	1.6	1.6	1.2	1.2	1.6	1.6	1.5	1.6	0.2
Total Sodium	mg/L	10.6	11.9	6.9	7.4	10.0	11.1	9.7	10.3	2.0
Total Sulfate	mg/L	15	17	16	14	19	18	17	17	2
Total Suspended Solids	mg/L	2 ND	4	-1 ND	7	13	16	7	6	7
Turbidity	NTU	1.1	ND	ND	4.1	6.5	11.0	5.7	5.3	4.2

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S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 7. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 790134.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	10/12/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	ND	1.1	5.5	12.0	4.0	2.7	5.1	4.0	4.2
Conductivity	umho/cm	321	394	271	312	231		306	312	61
Dissolved Oxygen	mg/L	11.76	7.73	10.00	8.80	9.80		9.62	9.80	1.50
Hardness ($CaCO_3$)	mg/L	134	159	112	115	101	100	120	114	23
pH	pH	7.85	8.17	8.50	8.39	8.05		8.19	8.17	0.26
Secchi Disk reading	feet	12.0	11.5	7.5	2.5	8.1	6.0	7.9	7.8	3.5
Temperature	^{o}C	11.80	19.91	23.90	20.75	13.96		18.06	19.91	5.02
Total Alkalinity	mg/L	93	110	78	81	71	79	85	80	14
Total Ammonia	mg N/L	0.013	0.027	0.003 T	0.003 T	0.002 T	0.014	0.010	0.008	0.010
Total Calcium	mg/L	37.2	43.2	28.4	26.9	26.2	26.9	31.5	27.7	7.1
Total Chloride	mg/L	19	31	20	29	10	8	20	20	9
Total Dissolved Solids	mg/L	200	250	180	210	160	150	192	190	37
Total Kjeldahl Nitrogen	mg N/L	0.25	0.46	0.36	0.61	0.22	0.25	0.36	0.31	0.15
Total Magnesium	mg/L	10.0	12.3	9.9	11.7	8.7	7.9	10.1	10.0	1.7
Total Nitrate	mg N/L	0.730	0.670	0.046	ND W	0.131	0.178	0.351	0.178	0.323
Total Nitrite	mg N/L	0.005	0.007	0.003	0.003	0.003	0.002	0.004	0.003	0.002
Total Organic Carbon	mg/L	3.8	4.7	3.1	6.1	2.8	1.4	3.7	3.5	1.6
Total Ortho Phosphate	mg P/L	0.002 T	ND W	0.003	0.003	0.001 T	ND W	0.002	0.003	0.001
Total Phosphorus	mg P/L	0.007	0.009	0.010	0.022	0.010	0.008	0.011	0.010	0.006
Total Potassium	mg/L	1.6	2.0	1.4	1.9	1.1	1.1	1.5	1.5	0.4
Total Sodium	mg/L	10.8	16.2	10.6	17.4	5.1	5.1	10.9	10.7	5.2
Total Sulfate	mg/L	16	22	20	20	15	14	18	18	3
Total Suspended Solids	mg/L	1 ND	5	5	11	5	5	5	5	3
Turbidity	NTU	1.2	ND	1.6	7.9	2.4	2.7	3.2	2.4	2.7

+ = Calculated value; not rounded to appropriate number of significant digits.
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Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 8. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 090252.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	4.7	1.1	14.0	22.0	3.9	9.1	4.7	8.7
Conductivity	umho/cm	410	482	435	357		421	423	52
Dissolved Oxygen	mg/L	11.82	6.92	11.20	9.09		9.76	10.15	2.22
Hardness ($CaCO_3$)	mg/L	164	185	170	122	123	153	164	29
pH	pH	7.92	8.13	8.49	8.38		8.23	8.26	0.26
Secchi Disk reading	feet	6.3	11.1	5.8	2.6	7.0	6.6	6.3	3.0
Temperature	^{o}C	11.96	21.11	24.60	20.47		19.54	20.79	5.37
Total Alkalinity	mg/L	112	129	116	88	91	107	112	17
Total Ammonia	mg N/L	0.019	0.075	0.006 T	0.006 T	0.019	0.025	0.019	0.029
Total Calcium	mg/L	44.6	48.9	43.0	29.1	32.8	39.7	43.0	8.4
Total Chloride	mg/L	31	45	45	38	19	36	38	11
Total Dissolved Solids	mg/L	260	310	290	240	200	260	260	43
Total Kjeldahl Nitrogen	mg N/L	0.41	0.53	0.57	0.68	0.34	0.51	0.53	0.13
Total Magnesium	mg/L	12.7	15.3	15.2	12.0	9.9	13.0	12.7	2.3
Total Nitrate	mg N/L	0.850	0.730	1.000	ND W	0.035	0.654	0.790	0.427
Total Nitrite	mg N/L	0.008	0.012	0.027	0.001 T	0.001 T	0.010	0.008	0.011
Total Organic Carbon	mg/L	6.0	6.4	6.6	5.4	3.9	5.7	6.0	1.1
Total Ortho Phosphate	mg P/L	0.003	0.005	0.001 T	0.007	0.002 T	0.004	0.003	0.002
Total Phosphorus	mg P/L	0.016	0.023	0.016	0.043	0.015	0.023	0.016	0.012
Total Potassium	mg/L	2.0	2.3	2.6	2.1	1.5	2.1	2.1	0.4
Total Sodium	mg/L	17.6	22.4	22.3	21.9	10.6	19.0	21.9	5.1
Total Sulfate	mg/L	20	25	26	22	17	22	22	4
Total Suspended Solids	mg/L	4	3 ND	3 ND	10	7	5	4	3
Turbidity	NTU	1.4	ND	3.5	11.0	2.5	4.6	3.0	4.4

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
C = Value caclulated from other independent parameters.
D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
E = Result is estimated due to high recovery of batch QC.
G = Result and RL are estimated due to initial calibration standard criteria failure.
H and HT = Recommended laboratory holding time was exceeded.
I and DM = Dilution required due to matrix interference; reporting limit raised.
ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 9. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 090250.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	6.5	4.9	13.0	17.0	17.0	11.7	13.0	5.7
Conductivity	umho/cm	342	349	310	287		322	326	29
Dissolved Oxygen	mg/L	12.49	8.31	9.17	8.72		9.67	8.95	1.91
Hardness ($CaCO_3$)	mg/L	140	151	130	109	117	129	130	17
pH	pH	8.02	8.08	8.25	8.36		8.18	8.17	0.16
Secchi Disk reading	feet	7.0	9.6	13.0	3.3	3.5	7.3	7.0	4.1
Temperature	^oC	10.77	18.67	24.00	20.68		18.53	19.68	5.62
Total Alkalinity	mg/L	99	103	98	84	86	94	98	8
Total Ammonia	mg N/L	0.004 T	0.009 T	0.008 T	0.003 T	0.011	0.007	0.008	0.003
Total Calcium	mg/L	38.4	42.3	35.2	27.0	31.3	34.8	35.2	6.0
Total Chloride	mg/L	22	24	20	21	14	20	21	4
Total Dissolved Solids	mg/L	220	220	210	190	180	204	210	18
Total Kjeldahl Nitrogen	mg N/L	0.29	0.30	0.31	0.46	0.35	0.34	0.31	0.07
Total Magnesium	mg/L	10.7	11.1	10.2	10.2	9.5	10.3	10.2	0.6
Total Nitrate	mg N/L	0.720	0.500	0.300	ND W	0.046	0.392	0.400	0.287
Total Nitrite	mg N/L	0.004	0.004	0.006	0.002	0.002	0.004	0.004	0.002
Total Organic Carbon	mg/L	4.3	3.1	2.9	3.4	3.6	3.5	3.4	0.5
Total Ortho Phosphate	mg P/L	0.003	ND W	ND W	ND W	0.005	0.004	0.004	0.001
Total Phosphorus	mg P/L	0.010	0.008	0.013	0.032	0.022	0.017	0.013	0.010
Total Potassium	mg/L	1.7	1.7	1.5	1.6	1.4	1.6	1.6	0.1
Total Sodium	mg/L	12.6	12.0	10.2	11.8	8.7	11.1	11.8	1.6
Total Sulfate	mg/L	16	18	17	18	16	17	17	1
Total Suspended Solids	mg/L	2 ND	2 ND	2 ND	6	9	4	2	3
Turbidity	NTU	2.7	ND	1.4	5.9	5.6	3.9	4.2	2.2

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
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A = Value reported is the mean of two or more determinations.
C = Value caclulated from other independent parameters.
D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
E = Result is estimated due to high recovery of batch QC.
G = Result and RL are estimated due to initial calibration standard criteria failure.
H and HT = Recommended laboratory holding time was exceeded.
I and DM = Dilution required due to matrix interference; reporting limit raised.
ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 10. WATER QUALITY DATA COLLECTED IN 2005 AT SAGINAW BAY STATION 060063.

PARAMETER	Units	5/9/2005	6/7/2005	7/11/2005	9/19/2005	11/2/2005	Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	1.2	1.6	6.4	8.1	3.5	4.2	3.5	3.0
Conductivity	umho/cm	333	319	287	271		303	303	28
Dissolved Oxygen	mg/L	11.71	7.76	9.67	9.13		9.57	9.40	1.64
Hardness ($CaCO_3$)	mg/L	139	128	115	114	120	123	120	10
pH	pH	8.08	8.54	8.40	8.37		8.35	8.39	0.19
Secchi Disk reading	feet	12.0	11.0	5.1	3.0	6.0	7.4	6.0	3.9
Temperature	^oC	13.25	21.65	24.30	20.03		19.81	20.84	4.71
Total Alkalinity	mg/L	94	90	79	82	88	87	88	6
Total Ammonia	mg N/L	0.007 T	0.012	0.004 T	0.002 T	0.007 T	0.006	0.007	0.004
Total Calcium	mg/L	38.3	33.6	29.0	29.1	31.8	32.4	31.8	3.8
Total Chloride	mg/L	22	23	23	19	17	21	22	3
Total Dissolved Solids	mg/L	210	200	190	180	190	194	190	11
Total Kjeldahl Nitrogen	mg N/L	0.34	0.32	0.43	0.53	0.33	0.39	0.34	0.09
Total Magnesium	mg/L	10.6	10.8	10.4	10.0	9.8	10.3	10.4	0.4
Total Nitrate	mg N/L	0.560	0.320	0.013	ND W	0.007 T	0.225	0.167	0.267
Total Nitrite	mg N/L	0.004	0.004	0.001 T	0.002	0.001 T	0.002	0.002	0.002
Total Organic Carbon	mg/L	4.6	3.6	4.8	4.1	3.9	4.2	4.1	0.5
Total Ortho Phosphate	mg P/L	0.002 T	0.001 T	ND W	0.003	0.002 T	0.002	0.002	0.001
Total Phosphorus	mg P/L	0.008	0.008	0.012	0.025	0.013	0.013	0.012	0.007
Total Potassium	mg/L	1.7	1.6	1.6	1.5	1.4	1.6	1.6	0.1
Total Sodium	mg/L	10.9	12.4	11.6	11.3	9.5	11.1	11.3	1.1
Total Sulfate	mg/L	16	18	19	18	17	18	18	1
Total Suspended Solids	mg/L	0 ND	2 ND	6	10	6	5	6	4
Turbidity	NTU	ND	ND	3.3	6.0	2.4	3.9	3.3	1.9

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
C = Value caclulated from other independent parameters.
D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
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K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
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Q = Quantity of sample insufficient to perform analyses requested.
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R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 11. TRACE METALS AND MERCURY DATA AND RULE 57 WATER QUALITY VALUES FOR SAMPLES COLLECTED IN SAGINAW BAY DURING 2005.

Station #060062	**9-May-05**	**7-Jun-05**		**11-Jul-05**	**19-Sep-05**		**12-Oct-05**	**2-Nov-05**	**MEAN**	**Rule 57 WQV**
Cadmium (ug/L)	0.00824	0.00810		0.00387	0.00472		NS	0.00565	0.0061	2.53
Chromium (ug/L)	-0.06852	0.00860		-0.06001	0.08700	CCB	NS	0.17800	0.0290	85.0
Copper (ug/L)	0.87900	1.28000		0.75400	0.60900		NS	0.61500	0.8274	10.3
Lead (ug/L)	0.08490	0.07980		0.05640	0.21100		NS	0.28700	0.1438	12.3
Nickel (ug/L)	0.95700	1.05000		0.88700	0.84900		NS	1.13000	0.9746	59.8
Zinc (ug/L)	1.79000	1.65000		0.96000	3.37000		NS	1.13000	1.7800	135.9
Mercury (ng/L)	0.68000	0.21000	MSD	0.26000	0.27000		NS	0.54000	0.3920	1.3
Hardness (mg/L)	130	127		113	114		NS	108	118	
Station #060063	**9-May-05**	**7-Jun-05**		**11-Jul-05**	**19-Sep-05**		**12-Oct-05**	**2-Nov-05**	**MEAN**	**Rule 57 WQV**
Cadmium (ug/L)	0.00631	0.00347		0.00313	0.00490		NS	0.00374	0.0043	2.50
Chromium (ug/L)	-0.06027	0.07800		-0.09811	0.08700	CCB	NS	0.17900	0.0371	87.8
Copper (ug/L)	1.02000	1.51000		0.87100	0.63200		NS	0.64600	0.9358	10.7
Lead (ug/L)	0.03860	0.03680		0.03910	0.13800		NS	0.18200	0.0869	12.9
Nickel (ug/L)	1.02000	0.98700		0.92300	0.85100		NS	1.20000	0.9962	62.0
Zinc (ug/L)	0.91000	1.13000		2.94000	1.63000		NS	1.48000	1.6180	140.8
Mercury (ng/L)	0.35000	0.52000	MSD	0.36000	0.40000		NS	0.38000	0.4020	1.3
Hardness (mg/L)	139	128		115	114		NS	120	123	
Station #090252	**9-May-05**	**7-Jun-05**		**11-Jul-05**	**19-Sep-05**		**12-Oct-05**	**2-Nov-05**	**MEAN**	**Rule 57 WQV**
Cadmium (ug/L)	0.00856	0.00562		0.00483	0.00774		NS	0.00424	0.0062	2.50
Chromium (ug/L)	-0.00802	0.19300		-0.00957	0.26000	CCB	NS	0.08100	0.1033	105.0
Copper (ug/L)	1.24000	2.57000		1.63000	1.18000		NS	0.73000	1.4700	12.9
Lead (ug/L)	0.15600	0.07830		0.07000	0.36600		NS	0.18300	0.1707	14.0
Nickel (ug/L)	1.26000	1.52000		1.42000	1.20000		NS	1.25000	1.3300	74.5
Zinc (ug/L)	1.44000	3.30000		4.03000	1.88000		NS	2.30000	2.5900	169.4
Mercury (ng/L)	0.68000	0.31000	MSD	0.41000	0.60000		NS	0.37000	0.4740	1.3
Hardness (mg/L)	164	185		170	122		NS	123	153	
Station #320189	**9-May-05**	**7-Jun-05**		**11-Jul-05**	**19-Sep-05**		**12-Oct-05**	**2-Nov-05**	**MEAN**	**Rule 57 WQV**
Cadmium (ug/L)	0.00405	0.00341		0.00199	0.00329		0.00475	0.00374	0.0035	2.50
Chromium (ug/L)	-0.05719	-0.00617		-0.01488	0.01587	CCB	0.19700	-0.00626	0.0214	83.7
Copper (ug/L)	0.50200	0.83200		0.53000	0.52100		0.59900	0.56000	0.5907	10.2
Lead (ug/L)	0.14200	0.11400		0.07520	0.13500		0.20800	0.27100	0.1575	12.1
Nickel (ug/L)	0.82700	0.84900		0.79200	0.89800		0.85200	1.14000	0.8930	59.0
Zinc (ug/L)	1.42000	1.00000		1.89000	5.69000		1.77000	1.03000	2.1333	134.0
Mercury (ng/L)	0.39000	0.36000	MSD	0.40000	0.34000		0.38000	0.49000	0.3933	1.3
Hardness (mg/L)	123	118		101	120		112	124	116	

CCB = Continuing calibration blank exceeded quality control criteria.
LCQC = Laboratory control exceeded quality control criteria.
MSD = Matrix spike duplicate exceeded quality control criteria.
NS = Not sampled.

TABLE 12. WATER QUALITY DATA COLLECTED IN 2005 AT GRAND TRAVERSE BAY STATION 450132.

PARAMETER	Units	4/5/2005		8/3/2005		Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	2.0		1.3		1.7	1.7	0.5
Conductivity	umho/cm	295		280		288	288	11
Dissolved Oxygen	mg/L	15.09		8.74		11.92	11.92	4.49
Hardness ($CaCO_3$)	mg/L	129		131		130	130	1
pH	pH	7.67		7.75		7.71	7.71	0.06
Secchi Disk reading	feet	37.0		34.0		35.5	35.5	2.1
Temperature	^{o}C	1.43		22.76		12.10	12.10	15.08
Total Alkalinity	mg/L	98		100		99	99	1
Total Ammonia	mg N/L	0.008	T	0.018		0.013	0.013	0.007
Total Calcium	mg/L	33.8		34.0		33.9	33.9	0.1
Total Chloride	mg/L	10		11		11	11	1
Total Dissolved Solids	mg/L	190		190		190	190	0
Total Kjeldahl Nitrogen	mg N/L	0.15		0.29		0.22	0.22	0.10
Total Magnesium	mg/L	10.9		11.2		11.1	11.1	0.2
Total Nitrate	mg N/L	0.270		0.240		0.255	0.255	0.021
Total Nitrite	mg N/L	0.001	T	0.005		0.003	0.003	0.003
Total Organic Carbon	mg/L	1.6		3.0		2.3	2.3	1.0
Total Ortho Phosphate	mg P/L	0.001	T	0.001	T	0.001	0.001	0.000
Total Phosphorus	mg P/L	0.004	T	0.007		0.006	0.006	0.002
Total Potassium	mg/L	1.2		1.3		1.3	1.3	0.1
Total Sodium	mg/L	6.6		7.9		7.3	7.3	0.9
Total Sulfate	mg/L	18		18		18	18	0
Total Suspended Solids	mg/L	-2	ND	-1	ND	-2	-2	1
Turbidity	NTU		ND		ND			

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
C = Value caclulated from other independent parameters.
D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
E = Result is estimated due to high recovery of batch QC.
G = Result and RL are estimated due to initial calibration standard criteria failure.
H and HT = Recommended laboratory holding time was exceeded.
I and DM = Dilution required due to matrix interference; reporting limit raised.
ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
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QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 13. WATER QUALITY DATA COLLECTED IN 2005 AT GRAND TRAVERSE BAY STATION 450133.

PARAMETER	Units	4/5/2005		8/3/2005		Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	2.1		1.0		1.6	1.6	0.8
Conductivity	umho/cm	294		278		286	286	11
Dissolved Oxygen	mg/L	14.81		8.99		11.90	11.90	4.12
Hardness ($CaCO_3$)	mg/L	123		124		124	124	1
pH	pH	7.76		7.77		7.77	7.77	0.01
Secchi Disk reading	feet	37.0		37.0		37.0	37.0	0.0
Temperature	^oC	1.25		22.67		11.96	11.96	15.15
Total Alkalinity	mg/L	97		100		99	99	2
Total Ammonia	mg N/L	0.012		0.010		0.011	0.011	0.001
Total Calcium	mg/L	31.6		31.3		31.5	31.5	0.2
Total Chloride	mg/L	10		11		11	11	1
Total Dissolved Solids	mg/L	190		190		190	190	0
Total Kjeldahl Nitrogen	mg N/L	0.19		0.19		0.19	0.19	0.00
Total Magnesium	mg/L	10.8		11.1		11.0	11.0	0.2
Total Nitrate	mg N/L	0.260		0.220		0.240	0.240	0.028
Total Nitrite	mg N/L	0.001	T	0.005		0.003	0.003	0.003
Total Organic Carbon	mg/L	2.0		2.4		2.2	2.2	0.3
Total Ortho Phosphate	mg P/L	0.001	T	0.001	T	0.001	0.001	0.000
Total Phosphorus	mg P/L	0.003	W	0.003	W	0.003	0.003	0.000
Total Potassium	mg/L	1.2		1.3		1.3	1.3	0.1
Total Sodium	mg/L	7.6		5.9		6.8	6.8	1.2
Total Sulfate	mg/L	18		18		18	18	0
Total Suspended Solids	mg/L	0	ND	2	ND	1	1	1
Turbidity	NTU		ND		ND			

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J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 14. WATER QUALITY DATA COLLECTED IN 2005 AT GRAND TRAVERSE BAY STATION 280288.

PARAMETER	Units	4/5/2005		8/3/2005		Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	0.9		1.1		1.0	1.0	0.1
Conductivity	umho/cm	293		275		284	284	13
Dissolved Oxygen	mg/L	14.26		8.88		11.57	11.57	3.80
Hardness ($CaCO_3$)	mg/L	130		126		128	128	3
pH	pH	7.75		7.91		7.83	7.83	0.11
Secchi Disk reading	feet	41.0		35.0		38.0	38.0	4.2
Temperature	^{o}C	1.80		23.10		12.45	12.45	15.06
Total Alkalinity	mg/L	100		102		101	101	1
Total Ammonia	mg N/L	0.009	T	0.017		0.013	0.013	0.006
Total Calcium	mg/L	34.1		31.9		33.0	33.0	1.6
Total Chloride	mg/L	10		11		11	11	1
Total Dissolved Solids	mg/L	190		190		190	190	0
Total Kjeldahl Nitrogen	mg N/L	0.14		0.18		0.16	0.16	0.03
Total Magnesium	mg/L	10.9		11.2		11.1	11.1	0.2
Total Nitrate	mg N/L	0.260		0.186		0.223	0.223	0.052
Total Nitrite	mg N/L	0.001	T	0.007		0.004	0.004	0.004
Total Organic Carbon	mg/L	1.8		1.2		1.5	1.5	0.4
Total Ortho Phosphate	mg P/L	0.001	T	0.001	T	0.001	0.001	0.000
Total Phosphorus	mg P/L	0.005		0.004	T	0.005	0.005	0.001
Total Potassium	mg/L	1.2		1.3		1.3	1.3	0.1
Total Sodium	mg/L	6.7		7.4		7.1	7.1	0.5
Total Sulfate	mg/L	17		18		18	18	1
Total Suspended Solids	mg/L	0	ND	0	ND	0	0	0
Turbidity	NTU		ND		ND			

\+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
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ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
QC = Quality control problems exist.
R = Result confiirmed by re-extraction and analysis.
S = Supernatant analyzed.
T = Reported value is less than the reporting limit. Result is estimated.
V = Value not available due to dilution.
W = Reported value is less then the method detection limit.

TABLE 15. WATER QUALITY DATA COLLECTED IN 2005 AT GRAND TRAVERSE BAY STATION 280289.

PARAMETER	Units	4/5/2005		8/3/2005		Mean	Median	Standard Deviation
Chlorophyll *a*	ug/L	1.4		1.0		1.2	1.2	0.3
Conductivity	umho/cm	294		277		286	286	12
Dissolved Oxygen	mg/L	14.72		8.87		11.80	11.80	4.14
Hardness ($CaCO_3$)	mg/L	141		124		133	133	12
pH	pH	7.70		7.81		7.76	7.76	0.08
Secchi Disk reading	feet	43.0		38.0		40.5	40.5	3.5
Temperature	^{o}C	1.63		22.57		12.10	12.10	14.81
Total Alkalinity	mg/L	98		101		100	100	2
Total Ammonia	mg N/L	0.009	T	0.009	T	0.009	0.009	0.000
Total Calcium	mg/L	38.7		31.0		34.9	34.9	5.4
Total Chloride	mg/L	10		11		11	11	1
Total Dissolved Solids	mg/L	190		190		190	190	0
Total Kjeldahl Nitrogen	mg N/L	0.16		0.16		0.16	0.16	0.00
Total Magnesium	mg/L	10.8		11.2		11.0	11.0	0.3
Total Nitrate	mg N/L	0.270		0.220		0.245	0.245	0.035
Total Nitrite	mg N/L	0.002		0.005		0.004	0.004	0.002
Total Organic Carbon	mg/L	1.9		1.5		1.7	1.7	0.3
Total Ortho Phosphate	mg P/L		ND W	0.001	T	0.001	0.001	0.000
Total Phosphorus	mg P/L	0.006		0.002	W	0.004	0.004	0.003
Total Potassium	mg/L	1.2		1.3		1.3	1.3	0.1
Total Sodium	mg/L	6.4		6.2		6.3	6.3	0.1
Total Sulfate	mg/L	18		18		18	18	0
Total Suspended Solids	mg/L	-1	ND	0	ND	-1	-1	1
Turbidity	NTU		ND		ND			

+ = Calculated value; not rounded to appropriate number of significant digits.
@ = Mean includes samples with concentration below level of quantification.
** = Not included in statistical calculations.
A = Value reported is the mean of two or more determinations.
C = Value caclulated from other independent parameters.
D and DL = Analyte value quantified from a dilution(s); reporting limit raised.
E = Result is estimated due to high recovery of batch QC.
G = Result and RL are estimated due to initial calibration standard criteria failure.
H and HT = Recommended laboratory holding time was exceeded.
I and DM = Dilution required due to matrix interference; reporting limit raised.
ID = Insufficient data for calculation.
J = Analyte was positively identified. Value is an estimate.
JC = Result is estimated since confirmation analysis did not meet acceptance criteria.
K = RL(s) raised due to matrix interferences.
M = The level of the method preparation blank is reported in the qualifier column.
NA = Not analyzed.
ND = Observed result was below the quantification level.
P and ST= Recommended sample collection/preservation technique not used; reported result(s) is an estimate.
PI = Possible interference may have affetced the accuracy of the laboratory result.
Q = Quantity of sample insufficient to perform analyses requested.
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